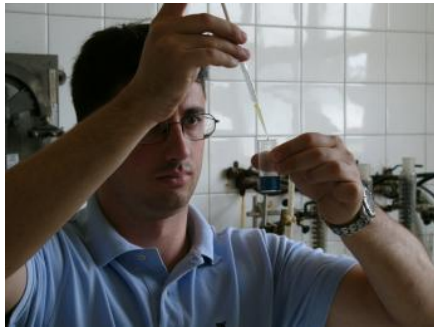
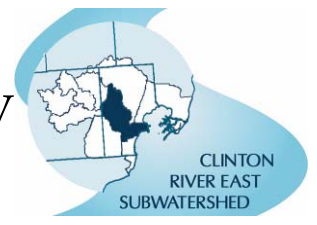


5. Problem Assessment & Stressor Summary



Introduction

Watershed management planning requires an understanding of the causes and sources of pollutants and other stressors (e.g., hydromodification) in the watershed, a quantifiable measurement of the pollutants and other stressors affecting the watershed, and a comparison of the current levels of pollutants and stressors against required water quality metrics (i.e., water quality standards). This information will indicate how much a pollutant or stressor must decrease to generate improvements in watershed conditions, as indicated by water quality standards and other types of water quality metrics.

This chapter presents significant information that is sometimes redundant with other chapters. This is because the analyses presented herein are best understood if all pertinent information is presented. Chapter 3 presented a detailed description of the causes and sources affecting conditions in the subwatershed, as well as the water quality metrics used to assess watershed conditions. Each of the causes and sources described in Chapter 3 result in one or more types of pollutants or stressors that adversely impact the watershed. This chapter provides a more detailed look at the primary pollutants and stressors generated by those causes and sources. This chapter also describes the analysis conducted to determine the percent reductions of specific pollutants and stressors necessary to improve water quality conditions, using water quality standards as the benchmark for measuring improvements.

It is important to note that the problem assessment and stressor summary for the subwatershed reflects the best sources of data available at the time of analysis. The analysis will change over time as a result of new data collected through the implementation of recent projects, such as the Clinton River Basin Watershed Initiative, and changes in the metrics used to assess water quality data, such as the adoption of new numeric nutrient criteria or improved indicators to assess pathogens. Watershed management planning is an iterative and dynamic process that requires the use of adaptive management, allowing strategies to evolve as new information becomes available. The analysis contained in this chapter will require regular re-assessment and re-evaluation as new data become available to ensure that strategies and priorities reflect the most accurate and most recent information.

Status of Water Quality

To determine the status of water quality in the subwatershed, it is necessary to have 1) water quality monitoring data and 2) the applicable water quality standards. Water quality standards are the measuring stick to determine if water quality is good, fair, or declining. Water quality standards consist of three components: designated uses, criteria, and an antidegradation policy. The first components, designated uses and criteria, are essential for measuring water quality in the subwatershed.

Where water quality does not support these designated uses, water quality is considered to be impaired. To determine if water quality supports the three designated uses, it is necessary to compare water quality monitoring

What are stressors?

The term “stressor” refers to the pollutants and other undesirable factors that degrade water quality conditions. Stressors affecting a watershed might include pathogens, nutrients, trash and debris, sediment, and contaminated sediments. In addition to pollutants, other stressors might also come in the form of undesirable changes to the natural features of a watershed, such as changes to habitat and natural hydrology.

Purpose of this Chapter

This chapter is provided to meet the requirements of the Environmental Protection Agency’s 319 grant funding program. The analyses and discussions presented herein are intended only to act as a part of a pollutant load reduction framework and are not meant to imply commitments towards the Phase II permit.

data from the subwatershed with numeric and narrative criteria – the second component of water quality standards.

As illustrated in the previous sections, a significant amount of water quality data and information have been collected at various locations since the early 1970s. Water quality has been sampled within the subwatershed at various locations since the early 1970s by a variety of agencies and organizations, including the Michigan Department of Environmental Quality (MDEQ) during their regular assessments of water quality throughout the State of Michigan. These monitoring data compared to water quality standards show that current water quality conditions in the subwatershed do not support designated uses. As a result, water quality in the subwatershed is impaired.

Status of Designated Uses

Based on the MDEQ-defined waterbody impairments and other information in Chapter 3, as well as the input summarized in Chapter 4, the designated uses that are threatened, impaired, or of indeterminate status have been identified and are presented in Table 5-1¹.

General Stressors

In addition to designated use impairments, the subwatershed also has beneficial use impairments that apply because it is located in the overall Clinton River Area of Concern (AOC) in the Great Lakes basin. To address these beneficial use impairments, stakeholders within the Clinton River Watershed are working together to develop an updated Remedial Action Plan (RAP). The updated RAP will describe the activities underway to restore the impaired beneficial uses and include the restoration criteria necessary to demonstrate when the beneficial use has been adequately restored. Currently, eight beneficial uses are considered impaired including: restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, degradation of benthos, restrictions on dredging activities, eutrophication or undesirable algae, beach closings, degradation of aesthetics and loss of fish and wildlife habitat. While restoration of these beneficial uses is an important goal for the subwatershed, the restoration criteria do not have the same regulatory significance as Michigan's water quality standards.

The Lake St. Clair Environmental Characterization defines a broad set of stressors that affect lands tributary to the lake. These stressors include:

- Land Development and Urban Expansion
 - Stormwater
 - Habitat Fragmentation and Destruction
 - Fire Suppression
 - Agriculture
 - Soil Erosion and Sedimentation
- Altered Hydrology
 - Water Level Changes
 - Draining of Wetlands
 - Filling Wetlands and Dredging Waterbodies
 - Diking and Breakwalls

Water Quality Classifications

Impaired

When water quality does not meet water quality standards, determined by comparing water quality monitoring data with numeric and narrative criteria that water quality must meet to support designated uses.

Threatened

When water quality currently meets water quality standards, but current conditions exhibit a declining trend that could result in a water quality impairment without corrective action.

1988 RAP Designated Use Impairments

The 1988 RAP listed the Clinton River downstream of the Red Run and the Spillway with the following impairments:

- Agriculture – due to TDS in excess of 500 mg/L (in large part due to soil types found in the basin);
- Warmwater fishery – due to degraded populations;
- Other aquatic life / wildlife – due to impacted communities and low dissolved oxygen; and
- Total Body Contact – due to presence of fecal coliform from sewer overflows.

Source: MDNR, 1988.

¹ The assessments presented herein are subject to change. New pollution sources, additional data, and updated water quality standards all might affect the status of the designated uses.

Table 5-1. Status of designated uses.

Designated Use	Waterbody / Reach	Status	Stressor
Agricultural Water Supply	All in the agricultural portion of the subwatershed	Threatened	Elevated PCB levels
Industrial Water Supply	Indeterminate	In-determinate	Elevated PCB levels; unknown distribution of industrial uses
Industrial Water Supply	Clinton River - East Main Branch (in Mt. Clemens)	In-determinate	Elevated Mercury levels; unknown distribution of industrial uses
Public Water Supply	All in the subwatershed near public water supplies	Threatened	Elevated PCB levels; cross contamination concerns between surface and groundwater
Navigation	Clinton River - West Main Branch	Threatened	Tree blockages inhibiting navigational use of the river (information from CRWC)
Other Aquatic Life / Wildlife	Clinton River - Central and East Main Branch	Impaired	Sediment
Other Aquatic Life / Wildlife	Clinton River	Threatened	PCBs and Mercury in fish tissue (implied impacts to other aquatic life)
Other Aquatic Life / Wildlife	Clear Spring Lake	Threatened	PCBs in fish tissue (implied impacts to other aquatic life)
Other Aquatic Life / Wildlife	All other inland lakes, reservoirs, impoundments	Threatened	Mercury in fish tissue (implied impacts to other aquatic life)
Other Aquatic Life / Wildlife	Lake St. Clair	Threatened	PCBs and Mercury in fish tissue (implied impacts to other aquatic life)
Other Aquatic Life / Wildlife	All waterbodies	Threatened	Elevated PCB levels
Warmwater Fishery	Clinton River - Central and East Main Branch	Impaired	Sediment
Warmwater Fishery	Clinton River - Central and East Main Branch	Threatened	Low dissolved oxygen (due to algae from nutrient elevation)
Warmwater Fishery	Clinton River	Threatened	Hydrology (flow variability)
Warmwater Fishery	Clinton River	Threatened	PCBs and Mercury in fish tissue (implied impacts to other aquatic life)
Warmwater Fishery	Clear Spring Lake	Threatened	PCBs in fish tissue (implied impacts to other aquatic life)
Warmwater Fishery	All other inland lakes, reservoirs, impoundments	Threatened	Mercury in fish tissue (implied impacts to other aquatic life)
Warmwater Fishery	Lake St. Clair	Threatened	PCBs and Mercury in fish tissue (implied impacts to other aquatic life)
Warmwater Fishery	All waterbodies	Threatened	Elevated PCB levels
Total Body Contact	Clinton River	Impaired	Pathogens
Total Body Contact	Clinton River - Central and East Main Branch	Threatened	Presence of algae from nutrient elevation
Total Body Contact	Lake St. Clair (Metropolitan Beach)	Impaired	Pathogens
Partial Body Contact	Clinton River	Impaired	Pathogens
Partial Body Contact	Clinton River - Central and East Main Branch	Threatened	Presence of algae from nutrient elevation
Partial Body Contact	Lake St. Clair (Metropolitan Beach)	Impaired	Pathogens

- Contaminants
 - Nutrient Loading
 - Toxic Contamination
 - Sediment Contamination
- Shoreline Modification, Shipping, and Boating
 - Vegetation Removal
 - Shoreline Hardening
 - Vessel Activity and Marina Development
- Invasive Species
 - Aquatic and Wetland Invasives
 - Terrestrial Invasives
 - Potential Invasives
- Natural Disturbances
 - Ice Storms
 - Windthrow

Obviously, not all of these stressors impact the subwatershed, nor are they necessarily at a scale appropriate for subwatershed planning. However, defining this framework allows one to see how this WMP fits into the bigger picture.

Determining Significant Stressors

A wide range of data and information are available on the Clinton River watershed. Review and analysis of recent data from studies and reports, also summarized in Chapter 3, helped to determine the most significant pollutants and stressors specifically in the subwatershed. Data and reports containing information on stressors used in this analysis include the following:

- Federal and state water quality monitoring data;
- Michigan Department of Environmental Quality's 2006 Sections 303(d) and 305(b) Integrated Report containing the Water Quality Standards Nonattainment List for Water Bodies Requiring TMDLs;
- State biological monitoring data for fish and macroinvertebrates;
- Development of Restoration Criteria in the Clinton River Area of Concern (Draft Final 2005);
- Lake St. Clair Environmental Characterization (2004); and
- Clinton River Assessment (DRAFT 2005).

Based on all of the data analyzed, the status of designated uses and related stressors, and the general stressor list, it has been determined that the most significant stressors in the subwatershed (and the most appropriate to address at this scale) include the following:

- Sediment;
- Phosphorus;
- Pathogens;
- Flow alterations;
- Contaminated sediments; and
- Habitat alterations.

Based on this list, the Subwatershed Advisory Group (SWAG) identified **sediment, phosphorus, pathogens, and flow alterations** as the top priorities to address in this plan, especially with respect to developing loading estimates and reduction targets.

Steps in the Load Duration Curve Approach

A load duration curve approach helps to identify the issues surrounding the impairment and to differentiate between pollutant sources. Steps for this approach are as follows:

1. Develop a flow duration curve for the stream by generating a flow frequency table and plotting the data points.
2. Translate the flow curve into a load duration curve. To accomplish this, multiply each flow value by the water quality target and by a conversion factor. Graph the resulting points.
3. Convert each water quality sample to a load by multiplying the water quality target concentration by the average daily flow corresponding to the day of sample collection and a conversion factor. Plot the individual loads on the graph.
4. Analyze location of data points with respect to the load duration curve. Points plotting above the curve represent deviations from the water quality target and the daily target load. Those plotting below the curve represent compliance with targets and the daily target load.
5. Interpret the final curves. The area beneath the load duration curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality targets.

Method for Quantifying Stressors and Establishing Reduction Targets

Significant stressors identified in the subwatershed will require strategic actions to reduce their impact on water quality and overall watershed health. To enable the selection and implementation of effective actions, it is important to first undertake an analysis that quantifies the stressor, identifies a numeric target, and determines if a reduction in the stressor is necessary to achieve the target. Quantifying the stressor for pollutants such as sediment, phosphorus, and pathogens, requires a way to determine how much of the pollutant is coming from particular sources in the subwatershed. The amount contributed by sources is referred to as the current pollutant load. The amount that sources should not exceed to achieve the numeric target is referred to as the target load. The method used to estimate the current and target pollutant loads in the subwatershed is called a load duration curve approach.

Estimating Pollutant Loads: The Load Duration Curve

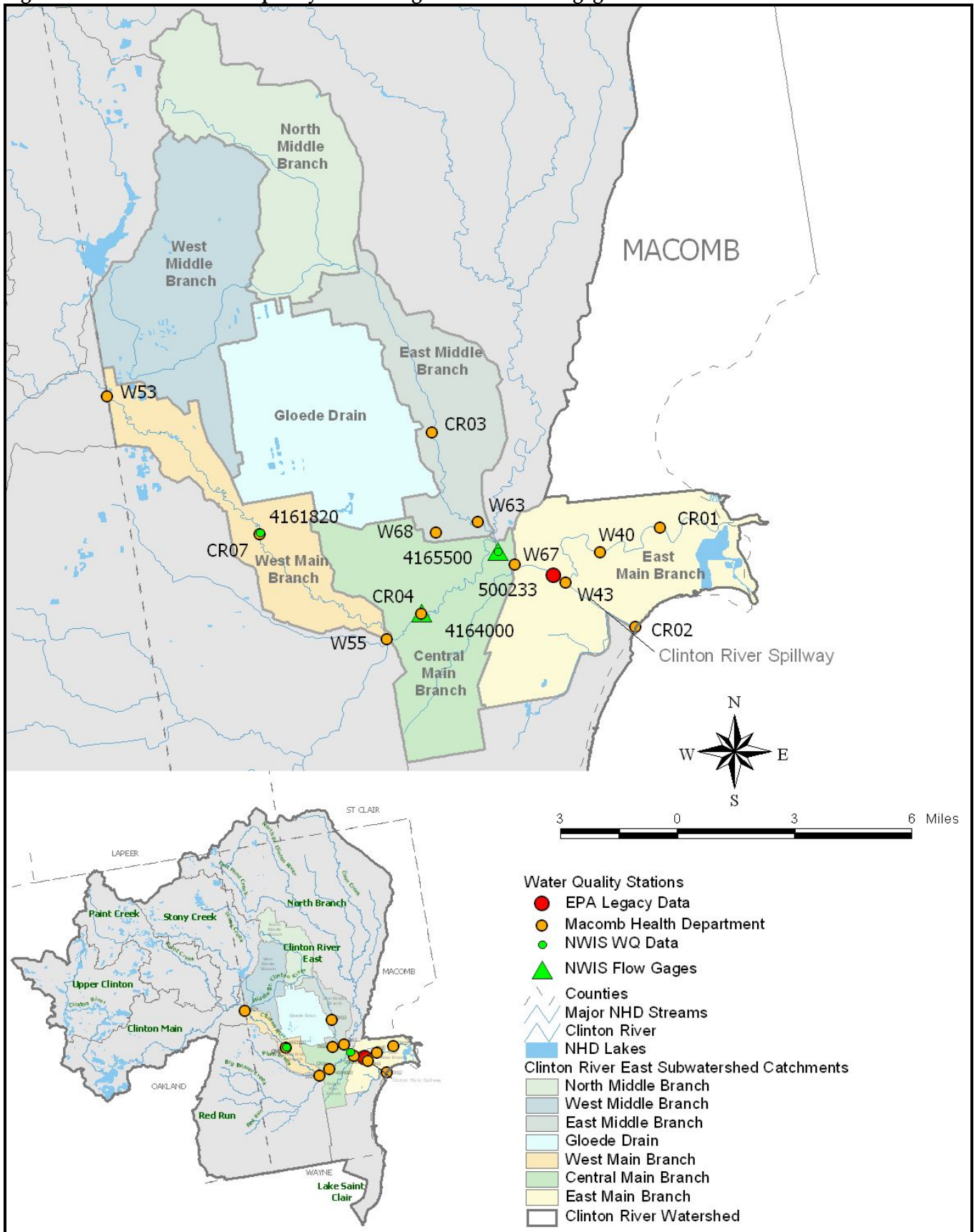
The load duration curve approach involves calculating the target loadings of a pollutant over the range of flow conditions expected to occur in the water body. The load reduction approach also considers critical conditions and seasonal variation. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions. The flow regimes are categorized into the following five “hydrologic zones” (Cleland, 2005):

- High flow zone: flows that plot in the 0 to 10-percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 50 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions.

The Clinton River at Moravian Drive at Mt. Clemens, Michigan gage (USGS gage 04105500) and the Clinton River near Fraser, Michigan gage (USGS gage 04164000) were used to estimate flows in the watershed. Flow at other points in the watershed was estimated using a unit-area approach. Continuous stream flow data are available from the USGS NWIS online database.

Water quality monitoring data used to determine the current and target pollutant loads in the subwatershed originate from several water quality monitoring stations. Figure 5-1 shows the locations of water quality monitoring stations in the subwatershed. Water quality monitoring stations are not located throughout the subwatershed; therefore, specific water quality monitoring stations are identified and used as representative stations. Table 5-2 lists the catchments and other geographic areas (i.e., subwatersheds) represented affecting water quality data at each water quality monitoring station.

Figure 5-1. Location of water quality monitoring and stream flow gages.



Extrapolating Stream Flows

When extensive flow data are not available, it is necessary to devise an approach for estimating flow at other points in the watershed. For purposes of estimating current pollutant loads, stream flows were extrapolated from the Clinton River stream flow record by using a multiplier based upon a comparison of the drainage areas.

Table 5-2. Representative water quality monitoring stations and associated catchments and subwatersheds.

Station ID	Primary Catchment	Other Catchments and Subwatersheds
CR03	East Middle Branch	North Middle Branch; West Middle Branch
4161820/ CR07	West Middle Branch	Clinton Main; Upper Clinton; Paint Creek; Stony Creek; Gloede Drain
4164000/ CR04	Central Main Branch (upper)	West Main Branch (downstream from 4161820/CR07); Red Run
4165500	Central Main Branch (lower)	Central Main Branch (downstream of 4164000); North Branch; East Main Branch (downstream of CR03)
500233	East Main Branch	Central Main Branch (downstream of 4165500)

Water quality station CR03 is located in the mid-section of the East Middle Branch catchment. Data from CR03 are representative of the water quality conditions not only in the upper portions of the East Middle Branch catchment, but also the upstream catchments: West Middle Branch, and North Middle Branch.

Water quality station 4161820/CR07 is located in the mid-section of the West Main Branch catchment. Data from 4161820/CR07 are representative of the water quality conditions in the upper portions of the West Main Branch catchment, but also of other subwatersheds located upstream: Clinton Main, Upper Clinton, Paint Creek and Stony Creek. Given there is no water quality monitoring station in the Gloede Drain catchment, the data from 4161820 are considered representative for Gloede Drain.

Water quality station 4164000/CR04 is located in the Central Main Branch, relatively close to the confluence of the tributaries draining the Red Run subwatershed and the mainstem of the Clinton River. As a result, data from these stations reflect the water quality contributions of the Red Run subwatershed, as well as the lower portions of the West Main Branch catchment located downstream from 4161820/CR07.

Water quality station 4165500 is also located in the Central Main Branch catchment, measuring the water quality conditions downstream of 4164000 in the Central Main Branch and CR03 in the East Main Branch catchments. Data from this water quality monitoring station also reflect water quality contributions from the North Branch subwatershed.

Water quality station 500233 is located in the East Main Branch catchment. Data from this station reflects water quality contributions from the downstream portions of the Central Main Branch catchment and a portion of the East Main Branch catchment downstream of 4165500.

There are other water quality monitoring stations located within the subwatershed; however, data from these stations were not used for purposes of this analysis because the data set is too limited or the data are not recent.

The remainder of this chapter examines the significant stressors in the subwatershed – sediment, phosphorus, pathogens, and hydrologic flow. Information provided for each significant stressor provides a summary of

the sources, impacts, impairments, indicators, water quality standards, available data, pollutant load estimates and target reductions, critical areas, how to monitor progress and ideas for improvement.

Sediment

Sediment in urban watersheds is an important pollutant; causing problems and negative impacts while also transporting other pollutants that bind to sediment particles, including phosphorus. Quantitatively, sediment has been labeled the most important single pollutant in U.S. streams and rivers. Inorganic fine sediments are naturally present to some extent in all streams. However, in the last half century, excessive sediment of anthropogenic origin has caused enormous damage to streams throughout North America (Waters, T.F. 1995).

Sediment transported by moving water is described by the terms “suspended load” and “bedload.” The suspended load is comprised by the fraction of material that is mixed intimately with the flowing water and tends to make the water appear muddy. The suspended load may be further segregated to include the suspended solids and the dissolved solids. Suspended solids will settle through the water based on their own density given an opportunity; however, solids are often sporadically and repeatedly caught in local turbulent eddies and remain suspended. The bedload is comprised of the larger particles too heavy to be suspended, but rather pushed along near the streambed (Leopold, 1994).

All streams require a degree of bedload transport to maintain their pools, riffles, and meanders. Some substrate movement is beneficial because it allows fine sediment to be flushed out of the spaces between larger particles and ultimately downstream. However, if there is too much substrate movement, the channel may be too unstable to support healthy fish and invertebrate populations.

Sources

The main sources of sediment are the erosion of uplands, lateral movement of channels into streambanks, and down cutting of streambeds. Natural erosion is present almost everywhere and results from wind and water passing over land surfaces. Table 5-3 identifies some general sources and causes of sediment based on human activities. Not all of these sources are present in the subwatershed. Some, such as agricultural runoff, might be present in upstream subwatersheds and have an eventual impact on the subwatershed.

In the subwatershed, the likely predominant sources of sediment include stormwater runoff from urbanized areas and agricultural land.

Chapter 3 of this WMP presents information gathered through the visual assessment process on subwatershed conditions that could contribute to sediment loads. The road-stream crossing survey results presented in Table 3-3 show that a majority of assessment sites lack a 100-foot riparian buffer along all waterbodies. In fact only four sites (one on the Clinton River and three on the Middle Branch of the Clinton River) provide this amount. The unified stream assessment conducted at three locations in the subwatershed revealed bank failure, channel modification, and impacted buffers contributing to sediment loading. The assessed reach of the Gloede Drain contains one instance of steep-slope bank failure. The

Distinguishing Between Sources and Causes of Impairment

Sources

Description of where pollutants or stressors are coming from. These sources of impairment are the activities, facilities, or conditions that generate the pollutants that keep waters from meeting the criteria adopted by the states to protect designated uses, such as municipal sewage treatment plants, storm sewers, and modification of hydrology.

Causes

The reason a particular source contributes pollutants or other stressors that cause water quality impairments. Causes help to define how an activity introduces a pollutant or other stressor into the watershed and highlights the type of management strategy necessary to address contributions from a particular source.

assessed reach of the Healy Brook Drain contains two instances of bank failure and channel modification due to fallen trees, bank armoring, and check dams. The assessed Harrington Drain reach contains an impacted buffer with bare ground; log jams; five instances of bank failure; and one instance of channel modification requiring structural repair.

A 2005 study prepared for the Macomb County Public Works Office and the MDEQ (ECT, 2006) documented high to very high streambank erosion potential on the Middle Branch of the Clinton River from its point of beginning to Romeo Plank Road. These potentials are functions of the shear stresses on the streambanks, the geometry of the cross-section, and the amount and type of material that is available to be eroded.

In 2005, the MCPWO and volunteers collected field data on streambank conditions in the subwatershed. MCPWO and volunteers documented good conditions at all locations on the Clinton River, the spillway, Wilcox Drain, Kingsbury Drain, Harris Drain, and most locations on the Middle Branch and Harrington Drain. The Price Brook had three good and three fair locations. The Gloede Drain had two poor locations, the Longstaff Drain had a fair and poor location, the Harrington Drain had a poor location, the Healy Brook had a poor location, and the Middle Branch had two fair locations. Figure 3-9 in this WMP illustrates streambank conditions and locations requiring attention throughout the subwatershed.

In addition, streambank erosion, construction activities, and hydrological impacts to the subwatershed are also suspected sources of sediment. Other urban and agricultural sources of sediment located in upstream subwatersheds, including the North Branch, Stony Creek, Paint Creek, Upper Clinton, Clinton Main, and Red Run, also contribute sediment to the subwatershed.

As part of the visual assessment process, volunteers conducted Unified Subwatershed and Site Reconnaissance (USSR) surveys that examined potential pollutant sources in neighborhoods, streets, and storm drains. The USSR surveys also examined hot spots and pervious areas. Chapter 3 presents the overall results of the USSR surveys. The neighborhood source assessment and the street and storm drain survey examined 21 locations in the subwatershed. Of those assessed, 71% of the neighborhoods had curb and gutter and 50% of those were assessed as having 'clean and dry' curb and gutter. Sediment and organic material, such as leaves and lawn clippings had the largest pollution source potential in the curb and gutter. Through the neighborhood source assessment, 52% of neighborhoods were assessed as having significant sediment pollution potential. The street and storm drain survey revealed cracked roads at 30% of the locations. This condition may allow more sediment to be introduced into runoff as a result of the deteriorating concrete. On-street parking is permitted on 40% of the street areas, which requires more impervious area than streets without parking and also may interfere with street sweeping efforts, resulting in increased sediment loads in runoff. Of the seven areas included in the pervious area assessment, four sites displayed soil compaction and erosion.

Table 5-3. General sources of sediment.

Sources	Causes
Agricultural Runoff	Lack of Buffer Poor Conservation Practices Over Grazing of Livestock
Streambanks	Flow Fluctuations (see Hydrologic Flow) Livestock Access Human Access
Livestock in Stream	Unrestricted Access
Off-Road Vehicles	Unrestricted Access Lack of Buffer
Construction Site Runoff	Inadequate Soil Erosion and Sedimentation Controls
Road-Stream Crossings	Poor Maintenance Poor Construction Poor Design Human Access
Drainage Ditches	Ditch Cleanout without Soil Stabilization Flow Fluctuations (see Hydrologic Flow) Livestock Access Human Access
Sand for Winter Road	Application Practices Lack of Buffer Poor Clean Up Practices
Gravel Roads, Parking Lots and Driveways	Lack of Buffer Poor Maintenance
Loss of Material Around Storm Sewer System	Poor Construction Poor Maintenance
Mining Operations/Gravel Pits	Inadequate Soil Erosion and Sedimentation Controls

Impact and Impairment

Suspended sediment, through turbidity, reduces light penetration through the water thus reducing photosynthesis. Fish in nature avoid streams or stream reaches with high suspended sediment levels creating environments just as devoid of fish as if they had been killed. Deposited sediment increase the level of embeddedness of the stream bed (termed habitat reduction) resulting in a decrease of invertebrate populations and consequently in food available to fish. Embeddedness refers to the extent to which gravel and cobbles are surrounded or covered by fine sediment. Decay of deposited organic sediments can also negatively affect in-stream dissolved oxygen concentrations. This is known as the sediment oxygen demand (SOD).

Indicators

Direct measurement of the amount of sediment moving in the watercourse may be measured as the total suspended solids (TSS), total dissolved solids (TDS) and the bedload. Turbidity indirectly measures the amount of sediment by considering the amount of light passable through the water column. Conductivity may also be used to indirectly measure the dissolved solids.

In addition, indicators such as the embeddedness and fish and benthic macroinvertebrate population and diversity may also be used as indicators of sediment.

Water Quality Standards

The water quality standards in Michigan pertaining to sediment do not include any numeric values to serve as a benchmark for assessing the amount of sediment in a water body. As a result, it is necessary to develop a numeric target for sediment. For purposes of the CREW watershed management plan, a preliminary numeric target for sediment was selected by evaluating data from Ohio reference sites within the same ecoregion as the Clinton River watershed (OEPA, 1999). This preliminary numeric target uses TSS as the indicator because suspended solids provide an estimate of the potential magnitude of sediment as a stressor and the primary sediment sources. The Clinton River watershed is located in the Huron-Erie Lake Plain ecoregion and the 90th percentile TSS values of reference sites within this ecoregion are approximately:

- Headwaters (< 20 square miles): 50 mg/L
- Wadeable (20 < 200 square miles): 65 mg/L
- Small Rivers (200 < 1000 square miles): 75 mg/L

The TSS value for small rivers applies to the CREW and is used as the benchmark to determine if current sediment loads meet water quality standards.

Current and Target Load Estimates to Calculate Load Reduction Percentages

The TSS target value presented above serves as the numeric goal for suspended solids in the subwatershed. To determine if the current amount of sediment entering the subwatershed will meet or exceed the TSS target value, it is necessary to estimate the current amount of sediment entering the subwatershed from a variety of sources. This amount is referred to as the current sediment load. In addition to determining the current load, it is also necessary to identify the target load – the amount of sediment that sources can contribute without exceeding the TSS target value for the subwatershed. If the current load is greater than the target load, management activities are necessary to reduce the sediment load entering the subwatershed.

This section presents the estimated current and target sediment load at each representative water quality monitoring station and the associated percent reduction in sediment loads necessary to meet the TSS target value in the subwatershed.

The load duration curve approach estimated current and target sediment loads using monitoring data for total suspended solids and a combination of recent and extrapolated flow data. Available total suspended solids sampling data originate from U.S. Geological Survey's (USGS) National Water Information System (NWIS) and the Macomb County Health Department. Table 5-4 presents the available TSS data.

Table 5-5 presents the existing and target annual TSS load (metric tons per year) for the in-stream sampling locations in the subwatershed. In addition, Table 5-5 states the percent annual load reduction necessary to achieve the TSS target value of 75 mg/L.

Table 5-4. TSS data used to estimate current and target loads.

Station ID	Period of Record	Count	Avg. (mg /L)	Min. (mg /L)	Max. (mg /L)
CR03	9/20/2004 - 11/2/2005	26	72	1	620
4161820/CR07	9/16/2004 - 10/21/2005	27	43	1	280
4164000/CR04	9/20/2004 - 10/21/2005	26	86	1	296
500233	1/29/1990 - 10/8/1998	70	37	4	470

Table 5-5. Estimated existing annual loads and associated reductions by representative monitoring station.

Station ID	Existing Load (t/yr)	Target Load (t/yr)	Load Reduction (t/yr)
CR03	4,176	2,464	1,712 (-40%)
4161820/CR07	25,725	20,464	5,261 (-20%)
4164000/CR04	65,837	29,404	36,433 (-55%)
500233	25,483	44,748	n/a (0%)

The load duration curve approach to estimate TSS loads in the subwatershed indicates that three areas require significant TSS load reductions to achieve the 75 mg/L TSS target value. At all three locations, the existing loads were most likely to exceed target loads during high flow conditions.

Data from water quality monitoring station CR03 show that the existing TSS loads from the North, West, and East Middle Branch catchments require a 40 percent reduction to achieve the target load that will meet the TSS target value.

Data from water quality monitoring station 4164000 show that a 55 percent reduction in TSS loads from the Central and West Main Branch catchments is necessary to achieve the target load and the TSS target value; however, it is important to keep in mind that the Red Run Subwatershed also influences TSS loads at this point.

Data from water quality monitoring station 4161820/CR07 show that existing TSS loads from the West Main Branch catchment, which include contributions from the four upstream subwatersheds, require a 20 percent reduction to achieve the target TSS load that will meet the 75 mg/L TSS target value. Since data from 4161820 are considered representative of Gloede Drain for purposes of this analysis, the 20 percent reduction also applies to the load from the Gloede Drain catchment. Tributaries from the North Branch Subwatershed converge with the Clinton River downstream of the water quality monitoring stations that indicate the need for significant TSS load reductions; data from water quality monitoring station 500233 show that no TSS loads decrease and that no reductions are necessary at this point to achieve the TSS target value. It is unclear at this time if TSS load reductions are necessary downstream of water quality monitoring station 500233 in the East Main Branch catchment due to a lack of sufficient accurate water quality and flow data.

Load Reduction Goals by Catchment

To calculate the sediment load reduction goals by catchment, it is necessary to have an estimate of the sediment loading from the sources in each catchment. Using readily available information such as land use and precipitation data, the Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) model, is able to provide an estimated sediment load for each catchment. It is important to keep in mind that the STEPL model does not estimate sediment loads from streambank erosion or account for upstream sediment load contributions (Tetra Tech 2004); therefore, the estimated loads are likely to be less than the actual sediment load from each catchment – particularly those experiencing streambank erosion or significant contributions from upstream sources.

The total estimated sediment load for each catchment and the applicable percent load reduction provide the total estimated load reduction for each catchment. Given that the STEPL model does not account for streambank erosion, an additional 10 percent is added on to the estimated load. The additional 10 percent is an estimated number and may be higher or lower than the amount contributed by actual streambank erosion. This percentage will be updated if and when better data on contributions from streambank erosion become available. The additional 10 percent was not applied to the Middle Branch catchments because there are actual measured TSS data for these three catchments combined. Table 5-6 presents the estimated total sediment load from each catchment, including the additional 10 percent of the original estimated load to account for streambank erosion. Table 5-7 presents the estimated load reduction by catchment.

Table 5-6. Estimated annual TSS load and additional load to account for streambank erosion by catchment

Catchment	Estimated Sediment Load (ton/year)	Additional Load to Account for Streambank Erosion (10%) (ton/year)	Total Estimated Sediment Load (ton/year)
Gloede Drain	708	71	779
Central Main Branch	409	41	450
East Main Branch	933	94	1027
West Main Branch	320	32	352
East Middle Branch	4,176	(Actual water quality monitoring data used from CR03 representing all three catchments)	4,176
North Middle Branch			
West Middle Branch			

Table 5-7. Estimated TSS load reduction needed by catchment

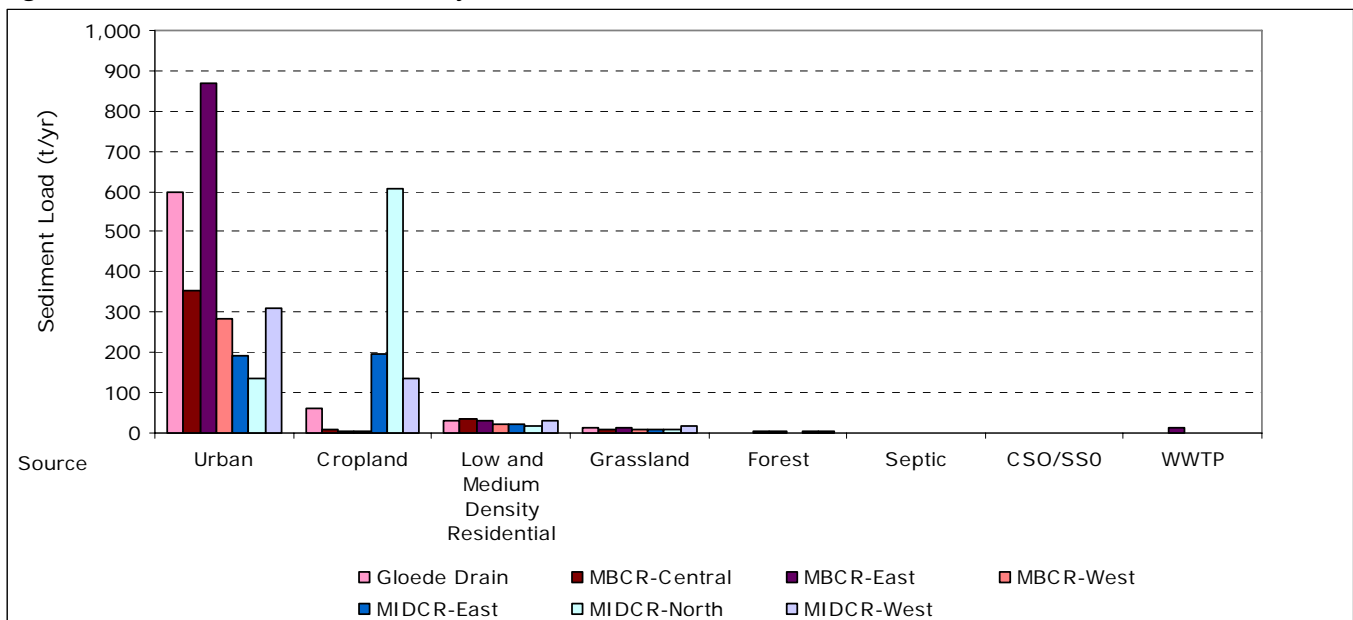
Catchment	Estimated Sediment Load Reduction Needed (tons/year)	
Gloede Drain	156	20% reduction estimated at 4161820 applied to total estimated sediment load of 779 t/yr
Central Main Br.	90	20% reduction estimated at 4161820 applied to total estimated load of 450 t/yr
East Main Br.	205	20% reduction estimated at 4161820 applied to total estimated load 1027 t/yr
West Main Br.	70	20% reduction estimated at 416820 applied to total estimated load of 352 t/yr
East Middle Br.	1,712	40% reduction from current load of 4,176
North Middle Br.		
West Middle Br.		

Critical Areas

Critical areas are the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. Identifying critical areas is an important step when determining how to achieve the TSS load reductions necessary to meet the TSS target value. The most significant sources of sediment loading in the subwatershed are stormwater runoff from urban land uses (e.g., commercial, industrial, institutional, transportation, multi-family dwellings, vacant developed land, and open space) and croplands, according to the analysis conducted using the STEPL model. Figure 5-2 presents a comparison of the relative contributions of sediment loading from different sources by catchment.

What is a critical area?
 A critical area is the geographic portion of the watershed that is contributing a majority of the pollutants and is having a significant impact on the waterbody (MDEQ 2000).

Figure 5-2. Estimated sediment load by source and catchment.



Although the STEPL model results provide only an estimate, the information is helpful in understanding the relative contributions of sediment loading from sources within the subwatershed and how to prioritize these sources when selecting management practices to achieve load reductions.

Within the urbanized areas, sediment picked up by the surface runoff is readily conveyed to a gutter (an impervious channelized flow path) which runs along most streets and washes into a traditional storm sewer drainage system, which quickly discharges the sediment to the nearby water courses. The traditional catch basin sumps offer some limited opportunity to remove sediment.

Within the rural and agricultural areas, controlling sediment in the adjacent stream corridor is generally more important than controlling exposed soil away from the river. This is because the primary mode of transportation in rural areas is by way of a ditch or a swale; overland sheet flow rarely occurs for distances longer than about 300 feet before the flow becomes channelized in some form. The ditches and swales are generally vegetated which serves to slow the water down and tends to offer some filtering.

Defining critical areas for sediment in the subwatershed requires consideration of the results from both the load duration curve analysis approach and the STEPL model. These results represent both measured and estimated data. Based on TSS load reductions and estimated source contributions of the sediment load, the critical areas to address in the subwatershed include those described below.

Those sources include those which contribute to the sediment loads that were estimated using monitoring data from the water quality monitoring stations that indicate the need for an annual TSS load reduction.

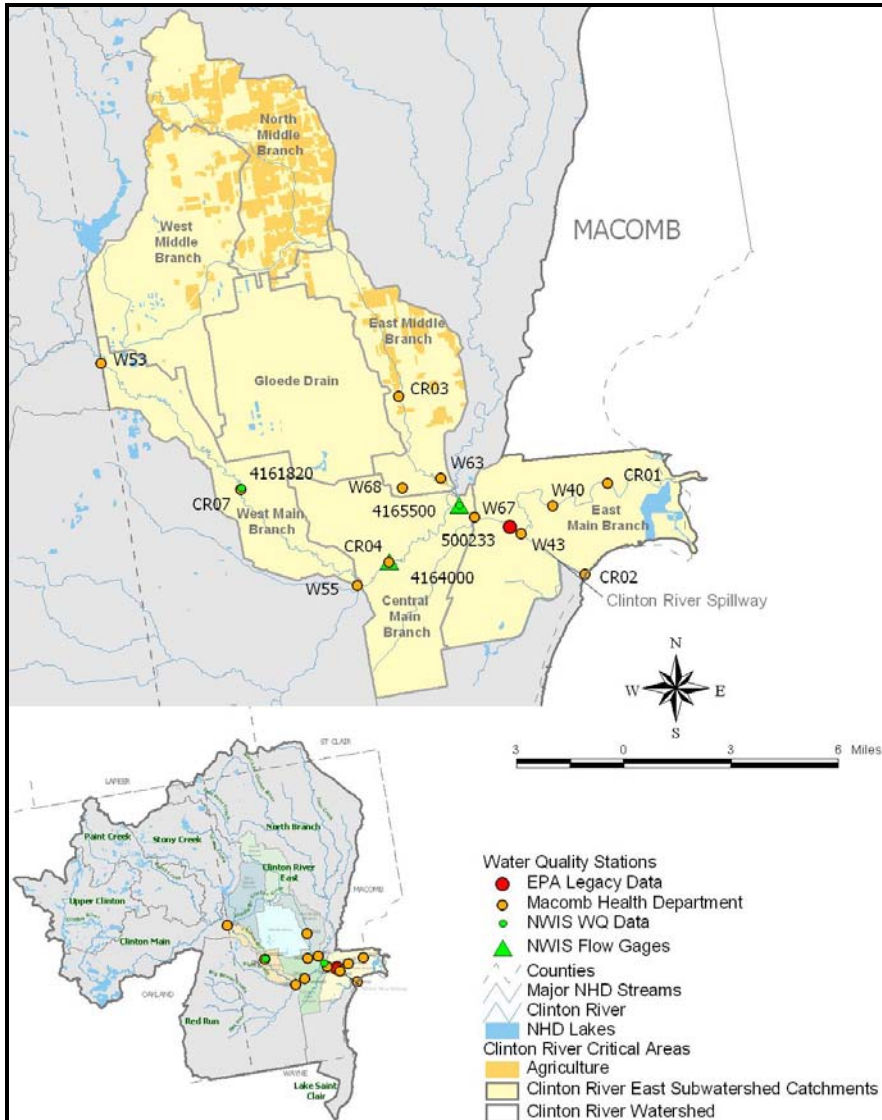
1 Agricultural Sources in the Middle Branch

Reductions of cropland sources of sediment in the East, North, and West catchments of the Middle Branch are necessary to achieve the estimated 40 percent reduction from the annual TSS load calculated for water quality monitoring station CR03. This equates a sediment load reduction of approximately 1,712 tons per year. Based on STEPL modeling results, urban and cropland sources in these three catchments contribute approximately 1,600 tons per year of sediment. The STEPL modeling results indicate that the North Middle Branch catchment contributes the greatest sediment loading from cropland, while the West Middle Branch contributes the least. Figure 5-3 illustrates the location of agricultural land uses in the Middle Branch.

2 Urban Sources in All Catchments

Results from STEPL clearly indicate that urban runoff is estimated to be the most significant source of sediment load in the subwatershed. Although there are some catchments that clearly contribute more of the load from urban sources than others, it is essential that all catchments in the subwatershed consider their urban sources as a critical area. By identifying all urban sources in the subwatershed as a critical area, each community in every catchment will share the responsibility to achieve their sediment load reduction targets. Figure 5-4 shows the location of urban areas in each of the catchments. Detailed information from the USSR surveys, particularly the neighborhood assessment and the street and storm drain surveys, will provide detailed locations of how to prioritize efforts in these catchments. Similar assessments in other areas of these catchments are likely needed to determine the potential for sediment pollution from curb and gutter, cracked streets, and other related urban land uses.

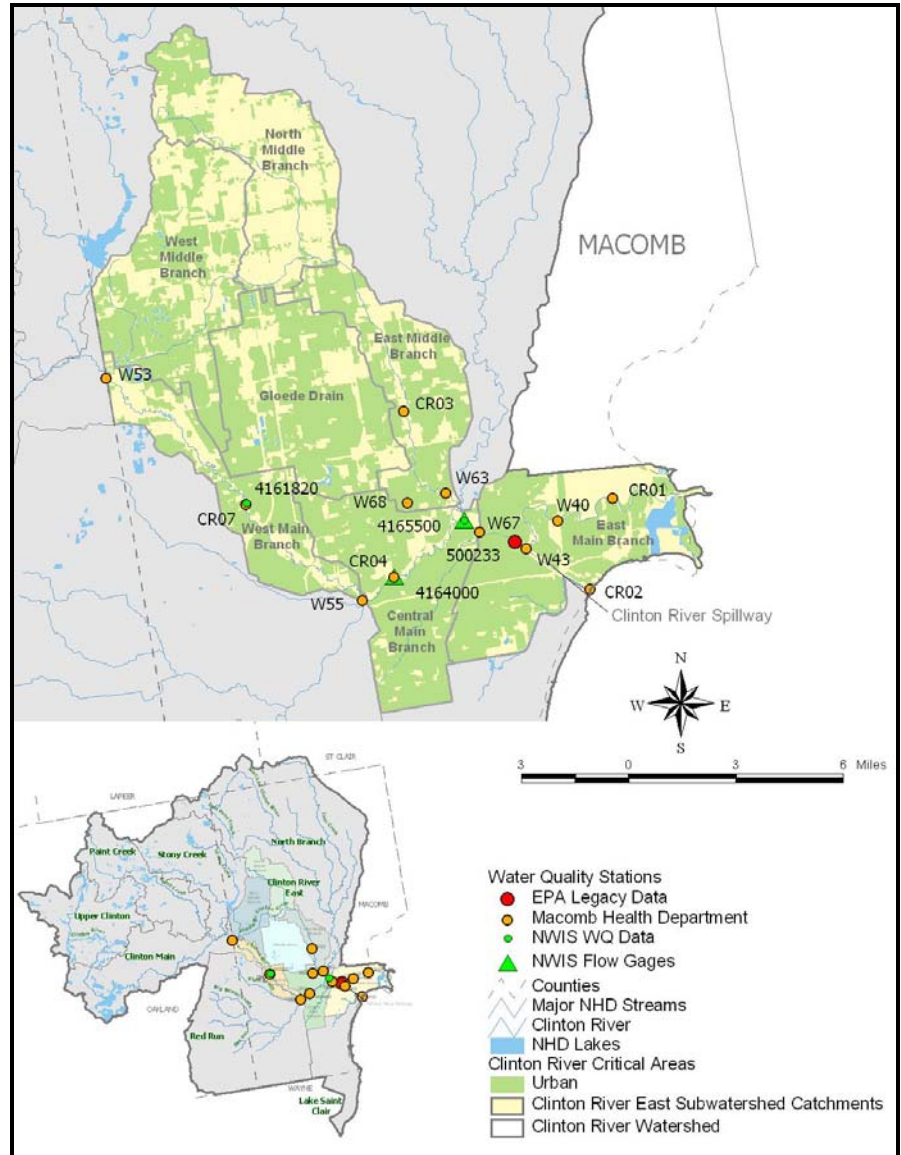
Figure 5-3. Agricultural land uses in the Middle Branch catchments identified as critical areas for sediment load reductions.



3 Known Areas of Exposed Soil

It is clear that other sources of sediment load exist in the subwatershed than those accounted for in STEPL. Since STEPL does not estimate sediment load from streambank erosion, it is likely that sediment load estimates for many catchments are underestimated. For example, the total estimated sediment load from the Middle Branch is approximately 4,172 tons/year according to estimates made using actual water quality monitoring data. The estimated amount from STEPL for the Middle Branch, however, is only 1,692 tons per year. The increased sediment load measured at CR03 is likely due to the significant amount of streambank erosion documented in the Middle Branch. Field data and recent studies mentioned in Chapter 3 and repeated above in the “Sources” subsection should help to pinpoint areas of exposed soil and prioritize restoration and stabilization activities. Based on known information, the Middle Branch should receive the highest priority for streambank restoration activities.

Figure 5-4. Urban land uses in all catchments identified as critical areas for sediment load reductions.



4 Soil Erosion from Construction Related Activities

Construction related activities are problems particularly when they are immediately adjacent to a water course or in an urbanized area with direct access to a storm sewer system and lacks the proper sediment controls. Although these areas were not considered in the STEPL model, it is well documented that soil erosion from construction related activities is a severe problem in rapidly developing areas and contributes significant sediment loads to the waterways. Portions of the CREW are rapidly developing. As mentioned in Chapter 2, the East Middle Branch catchment is projected to have a residential land use of 88 percent (up from 46 percent) by the year 2030. It is important to note that construction-related soil erosion control is addressed through a permitting program discussed in more detail in Chapter 7, and does not fall under the scope of this plan.

Monitoring Progress

Monitoring the reductions in the sediment load requires continued monitoring of TSS, as well as other indicators of sediment (e.g., turbidity, conductivity, benthic macroinvertebrates, pebble counts). The Macomb County Health Department conducts ongoing monitoring through its Surface Water Sampling Program, which includes TSS monitoring. The Clinton River Watershed Council's Stream Leaders student water quality monitoring program monitors turbidity and benthic macroinvertebrates.

Monitoring is recommended to include TSS to establish trends that build on the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring plans should also measure management practice effectiveness to determine if management practice implementation is successfully reducing sediment loading from sources in the subwatershed.

Future monitoring needs include developing a better flow and water quality data set downstream of water quality monitoring station 500233 in the East Main Branch Clinton River catchment. There is also a need for both a flow and a water quality monitoring site in the Gloede Drain catchment.

Chapter 9 presents the specific monitoring protocols to be implemented in support of this plan.

Improvement Ideas

In the urban areas, good housekeeping practices such as street sweeping and catch basin cleaning will help to reduce sediment loads. In addition, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer drainage system will decrease sediment loads. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. In addition, the use of swirl separators or sediment traps is another alternative.

Where agricultural areas contribute to sediment loads, animal access to the river should be limited and a buffer of ideally 100-feet or wider should be constructed. Where possible direct discharge of tile drains to the watercourses should be avoided. In addition, various conservation practices to minimize soil erosion should be employed. Participation in the Conservation Reserve Enhancement Program and making the rental rates for the land more appealing may be considered.

Stabilizing exposed soil adjacent to the streambanks and eroding streambanks may typically be accomplished with a vegetative approach (bioengineering). Some streambanks with extremely fast moving water next to it may require the use of hard armoring but in most cases other bioengineering techniques are available to divert or stabilize the forces from the moving water.

Findings from the road-stream crossing survey indicate areas in the CREW with potential problems related to hydrology, such as channelization and flashiness. Known hydrological problems exist in the lower portion of the subwatershed near the Clinton River Spillway, including decreased velocity and reverse flow, causing sediment deposition and build-up. Channel modifications and selective removal of logjams, such as those identified at Gloede Drain, Healy Brook Drain, and Harrington Drain may

be used to change the flow profile such that the movement of sediment deposition may be achieved.

Chapter 8 presents the specific actions to be taken towards achieving loading reductions for sediment, as well as other significant stressors.

Phosphorus

Nutrients, both nitrogen and phosphorus, are essential to aquatic ecosystems. However, high levels of nutrients can have a negative impact on water quality. Of the two nutrients, phosphorus is typically in short supply in fresh water and has the greatest potential for adversely impacting water quality. Phosphorus stimulates the growth of plankton and other aquatic plants consumed by fish and other animals. Thus, phosphorus is necessary for a productive and diverse aquatic ecosystem. However, elevated levels of phosphorus can lead to excessive aquatic plant growth and throw off the balance of ecosystem production and consumption. Too many aquatic plants with too few consumers means that plants start to decompose, dissolved oxygen levels needed to support aquatic life begin to drop, and fish and aquatic animal populations begin to decline.

Phosphorus usually exists in nature as part of a phosphate molecule. In a watershed, phosphorus is found as either organic or inorganic phosphate and can either be dissolved in water or suspended in water by attaching to particulate matter (e.g., sediment). Phosphorus cycles through a watershed and is constantly changing form. As it cycles, phosphorus usually moves downstream, dissolved in water and suspended in the water as decomposing plant and animal tissue. Phosphorus attached to particulate matter settles in bottom sediment, where it is used by some benthic macroinvertebrates or covered by additional sediment; when the bottom is stirred, phosphorus re-enters the water column and becomes available again to aquatic plants.

Sources

Phosphorus enters a watershed through both human and natural sources, although contributions from human sources are typically far greater than contributions from phosphate deposits and phosphate rich-rocks. The main sources of phosphorus in a watershed are usually from wastewater treatment plants, fertilizer from residential lawns, fertilizer and animal manure from agricultural lands, failing septic systems, soil erosion from streambanks and construction sites, and stormwater runoff from urban areas. Table 5-8 **Error! Reference source not found.** identifies some general sources and causes of phosphorus based on anthropogenic influences. Not all of these sources are present in the subwatershed. Some might be present in upstream subwatersheds and impact the Clinton River in this subwatershed.

Table 5-8. General sources of phosphorus.

Sources	Cause
Livestock	Unrestricted Access Lack of Buffer
Potential Illicit Connections	Function of Design Criteria Unnecessary Inflow Poor Maintenance Increased Development with Poor Stormwater Planning
Manure Storage	Poor Design Poor Construction Increased Development
Agricultural Runoff	Poor Nutrient Management Lack of Buffer
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste Lack of Buffer Wildlife
Failing Septic Systems	Poor Maintenance Poor Construction Poor Design Overloaded Used beyond design life
Leaky Sanitary Sewer	Poor Design Poor Construction Poor Maintenance
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration Stormwater Inflow Increased Development Inadequate storm drainage
Fertilizer Use (Non-Agricultural)	Fertilizer Application Lack of Buffer
Atmospheric Deposition	Causes Not Appropriate for this Plan but Education Needed
Increase in Naturally Occurring Sources	Loss of Wetlands
Residential Yard Waste	Poor Maintenance Poor Design of Facility
Dumpsters	Poor Construction Poor Maintenance
Golf Courses	Fertilizer Application Lack of Buffer
Publicly Owned Treatment Works (POTWs)	Plant Effluent Limits Poor Design Poor Maintenance
Combined Sewer Overflows (CSOs)	Limited Treatment Capacity Increased Stormwater Runoff from Impervious Surfaces Increased Development

In the subwatershed, the likely predominant sources of phosphorus include stormwater runoff from urban areas, failing septic systems and runoff from agricultural areas. The results from the Road-Stream Crossing Survey discussed in Chapter 3 found that proximity of the waterbodies to managed lawns or other urban residential neighborhoods is a common problem in the subwatershed. Managed lawns are potential sources of phosphorus in the subwatershed. In addition, results showed that almost all sites lacked a 100-foot riparian buffer. The results from the Unified Stream Assessment, also discussed in Chapter 3, indicates that the three assessed sites contain potential sources of phosphorus loading. For example, the Gloede Drain site contains an impacted buffer of less than 10

feet with managed turf from a nearby golf course that encroaches to the streambank. The Healy Brook site also contains an impacted buffer of 40 feet and a channel extends from an agricultural field to the drain with plenty of area available for reforestation. The Harrington Drain site contained three instances of utility impacts by probable septic system overflows or illicit connections to storm sewers, identified through evidence of dark brown discharge, sewage odor, toilet paper, and stains.

The neighborhood site assessments revealed that in three-fourths of assessed neighborhoods, at least 80% of lots had moderately to highly maintained turf grass. Highly managed turf grass is often the source of nutrients from fertilizer, grass clippings, and other yard waste. Based on field observations, 90% of neighborhoods showed indicators for excessive nutrients.

Due to the relationship of phosphorus to sediment, sources of sediment discussed in the previous section are also likely sources of phosphorus. These include streambank erosion, construction activities, and hydrological impacts that affect both erosion and stirring of bottom sediments. The Mt. Clemens wastewater treatment plant (WWTP) is also a potential source of phosphorus; however, it is subject to a regulatory program and is required to meet effluent limitations for phosphorus as a condition of its permit coverage. Other sources of phosphorus are located in upstream subwatersheds, including the North Branch, Stony Creek, Paint Creek, Upper Clinton, Clinton Main, and Red Run.

Impact and Impairment

Excessive levels of phosphorus can cause accelerated plant growth and algae blooms that can interfere with aesthetic and recreational uses of water. Decay of algae blooms and aquatic plants can cause odors and the suspended particulate matter can lead to increased turbidity, which reduces light penetration and increases water temperature. Decaying plant and animal tissue requires oxygen, resulting in decreased in-stream dissolved oxygen (DO) concentrations. Low DO levels can negatively impact fish and other important aquatic animals (e.g., benthic macroinvertebrates).

Indicators

Direct measurements of the amount of phosphorus in the watercourse typically focus on measuring orthophosphate using tests that measure total orthophosphate, total phosphorus, dissolved phosphorus, soluble reactive phosphorus, or insoluble phosphorus. Total phosphorus and soluble reactive phosphorus are most commonly used to measure phosphorus in lake and river systems, respectively.

Indirect indicators of phosphorus vary depending on the type of impacts the indicator is intended to measure. For example, if the concern is impact to aquatic life, the indirect indicators for phosphorus could include biological indicators such as fish and benthic macroinvertebrates; periphyton biomass; dissolved oxygen levels; or pH. When concerned about impacts to recreation, appropriate indirect indicators of phosphorus might include periphyton biomass or water quality (EPA 1999).

Water Quality Standards

The water quality standards in Michigan pertaining to phosphorus do not include any numeric values to serve as a benchmark for assessing the amount of phosphorus in a water body. As a result, it is necessary to develop a numeric target for phosphorus. The Macomb County Health Department uses a numeric target of 0.05 mg/L for total phosphorus (TP) (Macomb County Health Department, 2002). Until MDEQ develops and adopts new numeric nutrient criteria, this analysis applied the numeric target value for TP used by Macomb County at this time.

Current and Target Load Estimates to Calculate Load Reduction Percentages

The TP target value presented above serves as the numeric goal for phosphorus levels in the subwatershed. To determine if the current amount of phosphorus entering the subwatershed will meet or exceed the TP target value, it is necessary to estimate the current phosphorus load entering from a variety of sources. In addition to determining the current load, it is also necessary to identify the target load – the amount of phosphorus that sources can contribute without exceeding the TP target value. If the current load is greater than the target load, management activities are necessary to reduce the phosphorus load.

This section presents the estimated current and target phosphorus load at each representative water quality monitoring station and the associated percent reduction in phosphorus loads necessary to meet the TP target value in the CREW.

The load duration curve approach estimated current and target sediment loads using monitoring data for TP and a combination of recent and extrapolated flow data. Available total suspended solids sampling data originate from U.S. Geological Survey's (USGS) National Water Information System (NWIS) and the Macomb County Health Department. Table 5-9 presents the available TP data. Rows displayed in boldface type illustrate where the average exceeds the target value of 0.05 mg/L.

Table 5-9. TP data used to estimate current and target loads.

Station ID	Period of Record	Count	Avg. (mg/L)	Min. (mg/L)	Max. (mg/L)
4161820/CR07	4/4/1996 - 10/21/2005	70	0.08	0.01	0.24
4165500	4/3/1990 - 8/24/1995	23	0.14	0.01	0.35
500233	1/29/1990 - 10/8/1998	60	0.17	0.06	0.87
CR03	9/20/2004 - 11/2/2005	26	0.20	0.03	1.02
416400/CR04	9/20/2004 - 10/21/2005	26	0.29	0.03	0.63

Table 5-9 presents the existing and target annual TP load (tons per year) for the in-stream sampling locations in the CREW. In addition, Figure 5-10 states the percent annual load reduction necessary to achieve the TP target value of 0.05 mg/L.

Table 5-10. Estimated existing annual TP loads and associated reductions.

Station ID	Existing Load (t/yr)	Target Load (t/yr)	Load Reduction (%)
4161820/CR07	16	46	0%
4165500	80	101	0%
500233	86	101	0%
CR03	11	4	-65%
4164000/CR04	123	67	-45%

The load duration curve approach to estimate TP loads in the subwatershed indicates that two areas require significant TP load reductions to achieve the 0.05 mg/L TP target value. Data from water quality monitoring station CR03 show that the existing TP loads from the North, West, and East Middle Branch catchments require a 65 percent reduction to achieve the target load that will meet the TP target value. Data from water quality monitoring station 4164000 show that a 45 percent reduction in TP loads from the Central and West Main Branch catchments is necessary to achieve the target load and the TP target value; however, it is important to keep in mind that the Red Run Subwatershed also influences TP loads at this point. Data from water quality monitoring station 4161820/CR07, upstream from 4164000, show that existing TP loads from the West Main Branch catchment and the four upstream subwatersheds do not appear to require a reduction in TP to achieve the TP target value. This seems to indicate that a majority of the TP load measured at 416400 is likely from the Red Run subwatershed.

Tributaries from the North Branch Subwatershed converge with the Clinton River in the subwatershed downstream of the water quality monitoring stations that indicate the need for significant TP load reductions; data from water quality monitoring station 500233 show that TP loads decrease and that no reductions are necessary at this point to achieve the TP target value. It is unclear at this time if TP load reductions are necessary downstream of water quality monitoring station 500233 in the East Main Branch catchment due to a lack of flow data.

Load Reduction Goals by Catchment

To calculate the phosphorus load reduction goals by catchment, it is necessary to have an estimate of the phosphorus loading from the sources in each catchment. Using readily available information, such as land use and precipitation data, STEPL is able to provide an estimated phosphorus load for each catchment. As mentioned during the discussion of sediment loading, STEPL does not estimate loads from streambank erosion or account for upstream load contributions. Given the relationship between soil and phosphorus, it is likely that the estimated loads for both sediment and phosphorus will be less than actual loads from each catchment – particularly those experiencing streambank erosion or significant contributions from upstream sources.

The total estimated phosphorus load for each catchment and the applicable percent load reduction provide the total estimated load reduction for each catchment. Given that the STEPL model does not account for streambank erosion, and there is a strong connection between sediment and phosphorus, an additional load that estimates the amount of phosphorus associated with streambank erosion is added on to the

estimated load. The additional phosphorus load associated with streambank erosion is estimated by using the 10% additional sediment load estimated to account for streambank erosion and multiplying that number by a factor of 0.0005. MDEQ uses this factor when estimating the amount of sediment associated with a ton of sediment erosion. The additional estimated phosphorus load was not applied to the Middle Branch catchments because there are actual measured TP data for these three catchments combined. Table 5-11 presents the estimated total phosphorus load from each catchment, including the additional estimated load to account for streambank erosion.

Table 5-12 presents the estimated load reduction needed by catchment.

Table 5-11. Estimated phosphorus load by catchment.

Catchment	Estimated Phosphorus Load (ton/year)	Additional Load to Account for Streambank Erosion (0.0005 * 10% additional load for sediment)	Total Estimated Sediment Load (ton/year)
Gloede Drain	4.71	0.04 (0.0005*71)	5.11
Central Main Branch	2.94	0.02 (0.0005*41)	2.96
East Main Branch	5.72	0.05 (0.0005*94)	5.77
West Main Branch	2.68	0.02 (0.0005*32)	2.7
East Middle Branch	11	N/A	11
North Middle Branch			
West Middle Branch			

Table 5-12. Estimated TP load reduction needed by catchment.

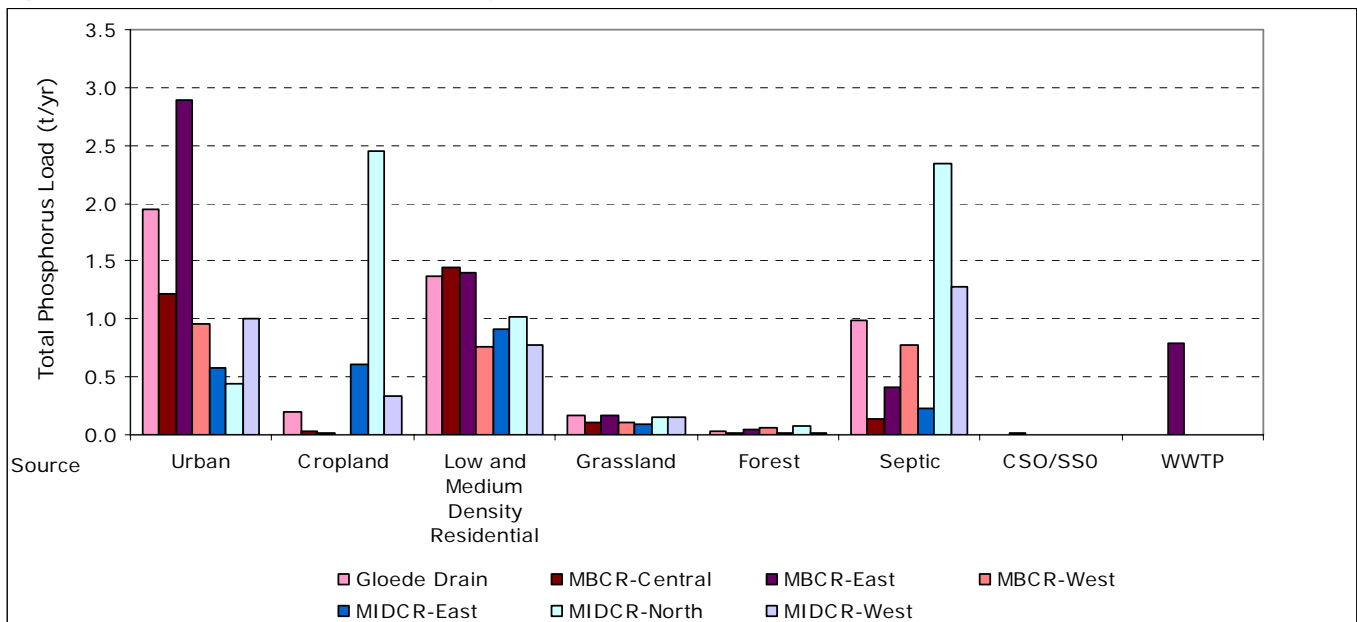
Catchment	Estimated Phosphorus Load Reduction Needed (tons/year)	
Gloede Drain	.72	14% reduction estimated at 4161820 applied to STEPL estimated load of 5.11 t/yr
Central Main Branch	.41	14% reduction estimated at 416820 applied to STEPL estimated load of 2.96 t/yr
East Main Branch	.81	14% reduction from STEPL estimated load 5.77 t/yr
West Main Branch	.38	14% reduction estimated at 416820 applied to STEPL estimated load of 2.7 t/yr
East Middle Br.	9	83% reduction from current load of 11 t/yr
North Middle Br.		
West Middle Br.		

Critical Areas

Critical areas are the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. Identifying critical areas is an important step when determining how to achieve the TP load reductions necessary to meet the TP target value. The most significant sources of phosphorus loading in the subwatershed are runoff from croplands, septic systems, and stormwater runoff from urbanized areas, according to the analysis conducted using the STEPL model. Figure 5-5 presents a comparison of the relative contributions of phosphorus loading from different sources by catchment. The STEPL model does not take into account streambank erosion or upstream load contributions. Therefore, the STEPL results do not reflect phosphorus loads associated with streambank erosion or contributions from the Warren WWTP in the Red Run Subwatershed. As a result, the TP loading from the STEPL analysis is less than the estimated annual load of TP presented in Table 5-11.

Although the STEPL model results provide only an estimate, the information is helpful in understanding the relative contributions of phosphorus loading from sources within the subwatershed and how to prioritize these sources when selecting management practices to achieve load reductions.

Figure 5-5. Estimated phosphorus load by source and catchment.



Results from the STEPL model indicate that urban sources of phosphorus, including those from low and medium density residential areas, are the most significant in the subwatershed. Urban sources of phosphorus can include fertilizer use, yard waste, pet waste, and automotive products deposited on roads and parking lots. Given the relationship of phosphorus to sediment (i.e., particulate phosphorus binds to sediment), surface runoff containing sediment is of concern. Within the urbanized areas, sediment picked up by the surface runoff is readily conveyed to a gutter (an impervious channelized flow path) which runs along most streets and washes into a traditional storm sewer drainage system, which

quickly discharges to the sediment to the nearby water courses. The traditional catch basin sumps offer some limited opportunity to remove sediment (and thus phosphorus).

Results from the STEPL model indicate that phosphorus loads from septic systems are the second most significant source. The North and West Middle Branch catchments contribute the highest phosphorus loading from septic systems. Septic systems, or on-site sewage disposal systems (OSDS) require proper siting and design, as well as routine inspection and maintenance to ensure proper functioning. Past studies in the Clinton River watershed indicate a 30 – 50 percent septic system failure rate (Ditschmann, 1995). A variety of factors can lead to failing septic systems, including soil wetness or seasonally high water tables, undersized systems, system age, limited space for the soil absorption field (Lee, 2005). Failing septic systems are not always obvious and are, therefore, difficult to detect and measure. An obvious sign of a failing septic system is sewage surfacing on a nearby lawn or over the drain field. In some instances, the soil over the drain field may appear soggy or the vegetation will appear lush. Transport of phosphorus from leaking septic systems depend on the location of the system, the type of soil, the amount and concentration of sewage, and the age of the system. Phosphorus that encounters soil saturated with water can move as much as several hundred feet (Solomon, 1993).

In addition to septic systems, the most significant source of phosphorus from agricultural land is located in the North Middle Branch catchment. The movement of phosphorus from agricultural land to surface water depends on site and management factors, as well as transport factors. Site and management factors include soil phosphorus levels, fertilizer application practices, and field management practices. Transport factors include erosion, distance between field and surface water or water flow. Erosion is the primary contributor to phosphorus loss on many fields, particularly tilled fields (Wortmann, 2005). Considerations for controlling sediment in agricultural areas are applicable to controlling phosphorus associated with erosion in agricultural areas. Critical areas for phosphorus loading from agricultural areas are fields adjacent to the stream corridor. A greater proportion of overland flow occurs within 100 feet of a channel. Overland sheet flow rarely occurs for distances longer than about 300 feet before the flow becomes channelized in some form. Phosphorus concentrations in runoff are likely to decrease as distance increases between the field and the adjacent channel (Wortmann, 2005).

Defining critical areas for phosphorus in the subwatershed requires consideration of the results from both the load duration curve analysis approach and the STEPL model. These results represent both measured and estimated data. Based on TP load reductions and estimated source contributions of the phosphorus load, the critical areas to address in the subwatershed include those described below.

Those sources include those which contribute to the sediment loads that were estimated using monitoring data from the water quality monitoring stations that indicate the need for an annual TSS load reduction. These areas are shown in Figure 5-6 labeled according to the discussion following the figure.

Based on TP load reductions and estimated source contributions of the phosphorus load, the critical areas to address are discussed below.

1 Urban Sources in All Catchments

Urban sources in all catchments contribute an estimated 16.7 tons per year of phosphorus to the subwatershed, which is approximately 59 percent of the overall estimated phosphorus load from all sources. Results from STEPL clearly indicate that urban runoff is estimated to be the most significant source of phosphorus load in the subwatershed. Although STEPL estimates that some catchments contribute more of the load from urban sources than others (e.g., East Main Branch of the Clinton River and Gloede Drain), it is essential that all catchments in the subwatershed consider their urban sources as a critical area. By identifying all urban sources in the subwatershed as a critical area, each community in every catchment will share the responsibility to achieve their sediment load reduction targets. Urban sources in all catchments are also critical areas for sediment; many of the measures taken to reduce sediment loads are likely to help reduce phosphorus loads simultaneously. Figure 5-4 shows the location of urban land uses in all catchments.

2 Agricultural Sources and Septic Systems in the Middle Branch

The three catchments of the Middle Branch contribute an estimated 11 tons per year of phosphorus to the subwatershed. Agricultural sources and septic systems are the two most significant sources of phosphorus in the Middle Branch, contributing an estimated 7.3 tons per year to the subwatershed – approximately 81 percent of the phosphorus load reduction needed to achieve the target value. Load reductions from these sources, coupled with reductions from urban sources, will help to achieve the reduction of 9 tons per year. Figure 5-6 shows the location of agricultural sources and septic systems in the Middle Branch.

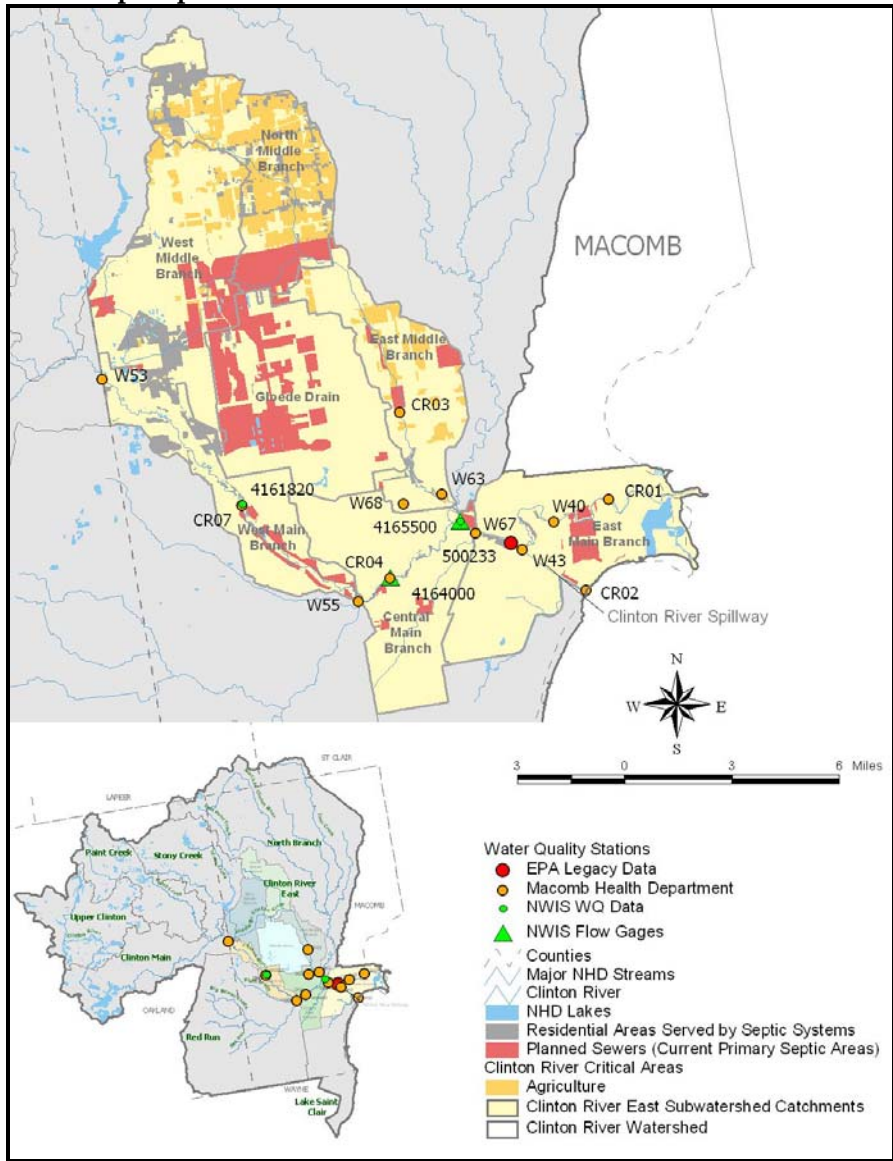
3 Known Areas of Exposed Soil

Field data and recent studies mentioned in Chapter 3 and repeated in this chapter under “Sediment” should help to pinpoint areas of exposed soil and prioritize restoration and stabilization activities. Based on known information, the Middle Branch should receive the highest priority for streambank restoration activities.

4 Soil Erosion from Construction Related Activities

These areas are problems particularly when immediately adjacent to a watercourse or in an urbanized area with direct access to a storm sewer system. Given the relationship of phosphorus to soil, controlling soil erosion from construction related activities will assist in reducing phosphorus loading in the subwatershed. Although these areas were not considered in the STEPL model, it is well documented that soil erosion from construction related activities is a severe problem in rapidly developing areas and contributes significant sediment loads to the waterways. Portions of the CREW are rapidly developing. As mentioned in Chapter 2, the East Middle Branch catchment is projected to have a residential land use of 88 percent (up from 46 percent) by the year 2030. It is important to note that construction-related soil erosion control is addressed through a permitting program discussed in more detail in Chapter 7, and does not fall under the scope of this plan.

Figure 5-6. Agricultural and septic system land uses identified as critical areas for phosphorus load reductions.



Monitoring Progress

Monitoring the reductions in the phosphorus load requires continued monitoring of total phosphorus, as well as other indicators of phosphorus (e.g., water clarity, dissolved oxygen). The Macomb County Health Department conducts ongoing monitoring through its Surface Water Sampling Program, which includes TP monitoring. The Clinton River Watershed Council’s Stream Leaders student water quality monitoring program monitors for phosphates.

Monitoring is recommended to include total phosphorus to establish trends that build off of the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring plans should also measure management practice effectiveness to determine if management practice implementation is successfully reducing phosphorus loading from sources in the subwatershed.

Future monitoring needs include developing a better flow and water quality data set downstream of water quality monitoring station 500233 in the East Main Branch catchment. There is also a need for both a flow and a water quality monitoring site in the Gloede Drain catchment.

The specific monitoring protocols to be implemented in support of this plan are presented in Chapter 9.

Improvement Ideas

In the urban areas, efforts to reduce the amount of phosphorus entering the storm sewer system will help to reduce the phosphorus load from urban runoff. This includes first taking action to reduce the source of phosphorus, such as amount of fertilizer leaving residential, commercial, industrial areas, as well as roadsides. In addition, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer system will also help to decrease phosphorus loads – less stormwater carrying phosphorus will travel through the system. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. In addition to reducing fertilizer use or promoting the use of phosphorus-free fertilizer, good housekeeping practices such as street sweeping and catch basin cleaning will help to reduce sediment loads that likely contain elevated levels of phosphorus.

To address phosphorus loads from failing septic systems, development and implementation of an effective performance-based on-site system management approach is key. As stated in Chapter 2, there is a documented lack of authority at the state and local levels to identify and remediate failing septic systems. Performance-based on-site programs include rigorous and ongoing system management, such as periodic inspections and required maintenance. The assumed failure rate is likely to decrease using this type of management approach, resulting in a reduced phosphorus loading.

The number of septic systems in the subwatershed is likely to change over time as population increases and more households are connected to sewer systems. SEMCOG predicts that the population of Macomb County will rise by 17.5 percent by the year 2030 and the number of households will increase by 32.6 percent. The area in the subwatershed that is treated by sewer systems is also predicted to increase from 64 percent to 78 percent. Using this information, in addition to the information about septic systems, loads from wastewater treatment plans are estimated to increase by 60 percent (largely due to serving a larger population). The number of future septic systems was based on predictions from SEMCOG that the area served by septic systems would drop from 47.47 square miles to 28.43 square miles. The failure rate was also assumed to decrease from 40 percent to 30 percent. However, until households currently served by septic systems are transferred to sewer systems, it is important to develop and implement performance-based on-site management programs.

Improvement ideas to reduce phosphorus loads from agricultural areas focus reducing the sources of phosphorus and limiting the transport of phosphorus. Management practices to reduce the sources of phosphorus include reducing the use of fertilizer or improving fertilizer application. Management practices related to sediment and erosion control on agricultural lands, such as conservation tillage or installation of vegetative

buffers, not only limit the transport of sediment, but also the transport of attached phosphorus particles. Where agricultural areas contribute to sediment loads, construction of 100-foot or wider vegetative buffers animal access to the river should be limited and a buffer of ideally 100-foot or wider should be constructed. Where possible, direct discharge of tile drains to the watercourses should be avoided. In addition various conservation practices to minimize soil erosion should be employed. Participation in the Conservation Reserve Enhancement Program and making the rental rates for the land more appealing may be considered.

Other actions to address erosion and sediment control have the potential to also reduce phosphorus loading. This includes stabilizing exposed soil adjacent to the streambanks and eroding streambanks using a vegetative approach (bioengineering). Some streambanks with extremely fast moving water next to it may require the use of hard armoring, but in most cases other bioengineering techniques are available to divert or stabilize the forces from the moving water. Addressing areas experiencing hydrologic modification could also reduce sedimentation and associated increased phosphorus loads.

The specific actions to be taken towards achieving loading reductions for sediment are presented in Chapter 8.

Pathogens

Pathogens are disease-causing microorganisms that are readily transported in stormwater runoff to streams and rivers. Three general categories of pathogens include bacteria, protozoans, and viruses. When found in water at elevated levels, pathogens can pose a serious health concern, potentially affecting water-based recreation and drinking water supplies. Illnesses associated with pathogens range from vomiting to death in sensitive populations. Risks to human health may vary depending on factors that influence the survival and reproduction of water-borne pathogens. Factors include temperature, sunlight, moisture, soil conditions, and settling in sediment (EPA, 2001).

Sources

Given the size and variability of pathogens, it is difficult to identify their sources and track their movement. Pathogens can enter watersheds from both point and nonpoint sources. Wastewater treatment plants and combined sewer overflows are typically the most significant point sources of pathogens. Nonpoint sources of pathogens in urban areas include failing sewer lines, pet waste, wildlife, and urban litter (EPA, 2001). In agricultural and rural areas, pathogens can originate from failing septic systems, uncontrolled manure storage areas, and land application of manure. Pathogens settle in bottom sediment and are prone to resuspension during storm events or from recreational activity. Table 5-13 identifies some general sources and causes of pathogens based on human activities. Not all of these sources are present in the subwatershed. Some, might be present in upstream subwatersheds and have an eventual impact in the subwatershed.

The likely sources of pathogens in the subwatershed include stormwater runoff from urban areas, failing septic systems, sediment resuspension related to altered hydrology, sanitary sewer overflows, wildlife, pet waste,

and illegal dumping and illicit connections into the storm sewer system. Chapter 2 documents past instances of sanitary sewer overflows in the subwatershed. Other sources of pathogens are located in upstream subwatersheds, particularly in the Red Run.

Impact and Impairment

The presence of pathogens in water has the potential to negatively affect public health and can impair recreational and drinking water uses. Primary and secondary contact with recreational water contaminated by pathogens presents an elevated risk for gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases. As mentioned in Chapter 3, information obtained from the Macomb County Health Department Website (2005) indicates that Metropolitan Park beach was closed at times during 1995, 1996, 1997, 1998, and 2000 due to excessive *Escherichia coli* (*E. coli*) levels.

Table 5-13. General sources of pathogens.

Sources	Cause
Illicit Connections	Poor Construction Practices Function of Design Criteria Unnecessary Inflow (e.g. connected downspouts and footing drains) Increased Development with Poor Stormwater Planning
Livestock	Unrestricted Access Lack of Buffer
Manure Storage	Poor Design Poor Construction Poor Maintenance
Animal Waste (Non-Agricultural)	Pet Owners Not Picking Up Waste Wildlife Lack of Buffer
Failed Septic Systems	Poor Design Poor Construction Poor Maintenance Overloaded Used beyond design life
Leaky Sanitary Sewer	Poor Design Poor Construction Poor Maintenance
Sanitary Sewer Overflows (SSOs)	Excessive Infiltration Stormwater Inflow Increased Development with Poor Stormwater Planning Inadequate storm drainage
Dumping	Lack of Adequate Disposal Facilities
Combined Sewer Overflows (CSOs)	Limited Transport and/or Treatment Capacity Increased Stormwater Runoff from Impervious Surfaces Increased Development

Indicators

Directly measuring pathogens in water presents a variety of challenges. As a result, bacteria associated with pathogens are measured as an indicator of the presence of pathogens. Fecal indicators, such as total coliform, fecal coliform, and *E. coli*, are commonly used indicator organisms. Although there is scientific support for the use of *E. coli* and other fecal indicators in determining the presence of pathogens, concerns exist about the correlation between the indicator, the presence of pathogens, and the incidence of disease (EPA, 2001). However, despite

these concerns, *E. coli* is one of the most frequently used and publicly recognized indicators for pathogens, particularly for purposes of beach health reporting.

Water Quality Standards

Water quality standards in Michigan contain numeric criteria for *E. coli* to protect total body contact recreation and partial body contact recreation designated uses. To protect total body contact recreation, in-stream water quality is not to exceed 300 *E. coli* per 100 milliliters. For partial body contact recreation, in-stream water quality is not to exceed a maximum of 1000 *E. coli* per 100 milliliters.

The component of the standard that applies to total body contact recreation (maximum of 300 counts/100 mL) was used to determine the extent of water quality exceedances in the subwatershed and identify critical areas.

Comparison of Current Concentration Data to the Water Quality Standard

The water quality standard for total body contact recreation presented above serves as the numeric goal for *E. coli*, a pathogen indicator organism. Rather than looking at *E. coli* loads from sources in the subwatershed, this section presents an analysis of the existing *E. coli* concentration data and directly compares these data to the water quality standard to indicate where a critical area might exist. Previous load reduction analysis conducted for the planning process indicates that significant load reductions throughout the subwatershed are necessary to achieve the water quality standard. Using a concentration-based approach is consistent both with the Macomb County Health Department's beach health reporting approach and the Michigan Department of Environmental Quality's approach for developing the pathogen Total Maximum Daily Load (TMDL) for the Red Run subwatershed upstream of the CREW. The nature of pathogens and *E. coli* as an indicator organism make it significantly challenging to estimate relative source contributions without the use of sophisticated and resource-intensive techniques (e.g., *E. coli* source tracking using DNA fingerprinting). It is appropriate to assume that all known and suspected sources of pathogens require significant attention to reduce pathogen loads to the subwatershed.

Table 5-14 presents the available *E. coli* data used to determine recent concentrations. These data are generated through Macomb County Health Department surface water quality monitoring programs. The geometric mean provides information on the average number of *E. coli* counts per 100 milliliters; counts above 300 indicate exceedances of the pathogen water quality standard. The percent reduction indicates how far the average concentration must drop to meet water quality standards – this is not a percent reduction in pathogen loads from sources. The number of samples exceeding the water quality standard out of the total number of samples (i.e., count) provides a percentage of samples that exceed the water quality standard. To determine where *E. coli* concentrations are of relatively greater concern, stations with monitoring data that demonstrate more than 60 percent of samples exceeding the water quality standard with a geometric mean greater than 60 percent above the standard have been flagged.

Table 5-14. *E. coli* data used to estimate current and target loads.

Station ID	Period of Record	Count	Geometric Mean (#/100mL)	Reduction %	# of Samples Exceeding 300 counts/mL	% of Samples Exceeding 300 counts/mL
4161820	4/4/1996 - 2/11/1998	41	150		7	17%
CR01	9/20/2004 - 10/21/2005	61	202		22	36%
CR02	9/20/2004 - 10/21/2005	56	103		14	25%
CR03	9/20/2004 - 10/21/2005	62	1641	-81.72%	49	79%
CR04	9/20/2004 - 10/21/2005	56	2162	-86.12%	52	93%
CR07	9/16/2004 - 10/21/2005	60	835	-64.05%	42	70%
W40	5/23/2000 - 9/16/2003	11	664	-54.85%	8	73%
W43	5/23/2000 - 9/16/2003	11	88		3	27%
W53	5/23/2000 - 9/16/2003	11	510	-41.12%	6	55%
W55	5/23/2000 - 9/16/2003	11	1097	-72.65%	9	82%
W63	5/23/2000 - 9/16/2003	11	975	-69.23%	10	91%
W67	5/23/2000 - 9/16/2003	11	1016	-70.47%	9	82%
W68	5/23/2000 - 9/16/2003	11	461	-34.97%	6	55%

Table 5-15 presents the existing and target annual *E. coli* load (billion cells per year) for the in-stream sampling locations in the CREW. In addition, Table 5-15 states the percent annual load reduction necessary to achieve the water quality standard for total body contact recreation of 300 *E. coli*/100 mL.

Table 5-15. Existing annual loads and associated needed reductions.

Station ID	Existing Load (10 ⁹ cells/yr)	Target Load (10 ⁹ cells/yr)	Needed Load Reduction (%)
4161820/CR07	522,538	742,588	0%
4164000/CR04	34,955,959	1,067,019	97%
CR03	2,250,858	103,173	95%
W43	9,292,872	1,623,808	82%

Critical Areas

For other stressors, critical areas are defined as the geographic portions of a watershed that contribute the greatest amount of a pollutant and have the most significant impact on the watershed. For *E. coli*, the analysis focuses on concentration data rather than loading data. Therefore, it is difficult to estimate the geographic portions of the watershed that contribute the greatest amount of pathogens. Concentration data can provide an understanding of what portions of the subwatershed have relatively higher or lower levels of pathogens; this provides an indication of which catchments might contribute a relatively greater pathogen load. Recommended critical areas for *E. coli* include those catchments represented at water quality monitoring stations with a geometric mean exceeding the water quality standard by more than 60 percent and more than 60 percent of samples exceeding the water quality standard. The prioritized critical areas associated with these water quality monitoring stations are described below in more detail.

1 Middle Branch

Monitoring data from two water quality monitoring stations, CR03 and W63, show *E. coli* concentrations exceeded water quality standards at the time of sampling. Without estimated load contributions by source category, information about land uses in these catchments (see Chapter 2) can help determine the potential sources of *E. coli*.

Predominant land uses in the Middle Branch catchments include residential (38 percent) and agriculture (25 percent). Of the three catchments, the North Middle Branch contains the highest percentage of agricultural lands. In addition, 93 percent of the land area in the North Middle Branch relies on septic systems – estimated to have a potential 30% to 50% failure rate. Within this critical area comprised of the three Middle Branch catchments, it is recommended that potential agricultural sources (e.g., uncontrolled manure storage areas, land application of manure and sewage sludge) and failing septic systems take first priority. Runoff from urbanized areas in all three catchments should also receive attention in an effort to reduce *E. coli* loads.

2 Central Main Branch Catchment

Three of the highlighted water quality monitoring stations – CR04, W55, W67 -- are located in the Central Main Branch catchment. This catchment is adjacent to the Red Run subwatershed; therefore, the *E. coli* concentrations in this catchment likely reflect upstream contributions and illustrates the need to work with the Red Run subwatershed to address *E. coli* loads.

3 West Main Branch Catchment

E. coli monitoring data from the water quality monitoring station CR07 represents conditions from the mid-portion of the West Main Branch catchment. Potential sources from this catchment might include septic systems, runoff from agricultural sources, as well as runoff from urban sources.

Monitoring Progress

Monitoring the progress of reducing pathogens will rely on existing *E. coli* monitoring efforts by the Macomb County Health Department. The Macomb County Health Department monitors for *E. coli* on a regular basis through the Macomb County Bathing Beach and Surface Water Quality Program. In addition, the Department conducts initial investigations of stormwater outfalls through the Illicit Discharge Elimination Program, which includes sampling for *E. coli*.

Another indicator of pathogens, fecal coliform bacteria, is monitored through the Clinton River Watershed Council's Stream Leaders student water quality monitoring program.

Continued *E. coli* monitoring will establish trends that build off of the existing dataset that serves as baseline data. In addition to monitoring for purposes of trend analysis, monitoring should also measure management practice effectiveness to determine if management practice implementation is successfully reducing *E. coli* loads from sources in the subwatershed. The issue of pathogen source identification is an important and challenging topic; as progress is made in this arena, it would be beneficial to incorporate source identification monitoring to help distinguish the sources of *E. coli* in the subwatershed.

Given the challenges associated with using *E. coli* as an indicator organism for pathogens, future monitoring needs include identifying an alternative indicator for pathogens. Future monitoring needs for *E. coli* also include the identification and use of acceptable source tracking techniques to aid in distinguishing anthropogenic sources of pathogens from wildlife and other natural sources.

The specific monitoring protocols to be implemented in support of this plan are presented in Chapter 9.

Improvement Ideas

In the urban areas, efforts to properly manage domestic pet waste and limit the populations of anthropogenic wildlife, such as geese, pigeons, raccoons, and rats, are likely to help reduce *E. coli* loads associated with urban runoff. In addition, management practices that promote infiltration while reducing the direct connection of impervious areas to the storm sewer drainage system will decrease *E. coli* loads. These types of management practices include porous pavement, green roofs, bioinfiltration, retention, detention and other low impact development techniques. Reducing the amount of stormwater runoff from urban areas will also help to alleviate the stress placed on separate and combined sanitary sewers that might have illicit connections to the storm sewer system or inflow/infiltration problems due to age or lack of adequate maintenance.

To address *E. coli* loads from failing septic systems, development and implementation of an effective performance-based on-site system management approach is key. As stated in Chapter 2, there is a documented lack of authority at the state and local levels to identify and remediate failing septic systems. Performance-based on-site programs include rigorous and ongoing system management, such as periodic inspections and required maintenance. The assumed failure rate is likely to decrease using this type of management approach, resulting in a reduced phosphorus loading.

Achieving *E. coli* load reductions in agricultural areas will likely necessitate the use of effective manure management techniques, including adequate manure storage, strategic land application of manure and sewage sludge, as well as restricted livestock stream access. Vegetated buffers previously discussed for other stressors will also aid in reducing the transport of *E. coli* to nearby streams and rivers.

The specific actions to be taken towards achieving loading reductions for sediment are presented in Chapter 8.

Hydrologic Flow

Stream flows vary in characteristic ways over time frames ranging from hours and days to seasons and years. The flow regime includes such factors as the magnitude and frequency of floods and low flow periods, the seasonal occurrence of various flow rates, and the rates of change of flow. The flow regime of a stream reflects the operation of the hydrologic cycle within its watershed. Climate, topography, geology, soils, vegetation, watershed size and shape, stream pattern, land use, water use, and dams all impact the timing and pathways of water movement to and through stream and hence the stream's flow regime.

Hydrologic flow is not a pollutant in the terms of heavy metals or pesticides, but does affect biota and stability of streams and rivers. Changes in hydrologic flow typically increase the volume, frequency, and peak discharges of the stream. These changes may cause streambank erosion, sedimentation, and poor conditions for plants, fish and macroinvertebrates. In addition the surface runoff from precipitation collects and transports various pollutants to the receiving waters thus not only affecting the flow characteristics in the receiving water but also the pollutant concentrations.

Sources

Hydrologic flow changes in receiving water courses are due to a loss of infiltration into the soil, a loss of evaporation, loss of storage or increased flow channelization. These occurrences are typical of development regardless of the new land use. For example in urban areas loss of infiltration, storage and evaporation result as impervious surfaces are created and the soil is compacted due to construction operations. Refer to the discussion on the relevance of impervious cover in Chapter 2 for additional information.

Another key cause of changes in hydrologic flow is the loss of storage from wetlands and floodplains. As discussed in Chapter 2, wetland coverage in the subwatershed is currently 5.7 percent of land area. The West Main Branch catchment is 9.9 percent wetlands (mostly adjacent to the river) and accounts for 18.4 percent of the subwatershed total. The East Main Branch catchment is 7.2 percent wetlands (mostly in low lying areas near Lake St. Clair) and accounts for 21 percent of the subwatershed total. Other catchments accounting for greater than 15 percent of the wetland total include the North Middle Branch and West Middle Branch catchments where the wetland acreage can be attributed in part to less intense urban development.

Table 5-16 summarizes various sources of changes to the hydrologic flows.

Table 5-16. Hydrologic flow change sources.

Sources	Cause
Increased Channelization	Impervious Surfaces Lack of Buffer More Hydraulically Efficient Drainage Systems Additional Drainage Systems Development with Poor Stormwater Planning
Loss of Infiltration	Impervious Surfaces Loss of Natural Areas Development with Poor Stormwater Planning Lack of Buffer Compacted Soils Turf Grass
Loss of Storage	Loss of Wetlands Loss of Low Areas Acceptable for Flooding Loss of Floodplain Development with Poor Stormwater Planning

Impact and Impairment

The typical changes in hydrologic flow due to development in the surrounding watershed include an increase in the flashiness of the watercourse, an increased peak flow, a reduction in the base flow due to loss of interflow and groundwater flow through the soil, and an increase in the total volume of water transported. A decrease of water is also possible if significant water withdrawals are occurring, however this is not the case in this watershed.

Increases in peak flow rates may literally wash benthic macroinvertebrates, fish, amphibians and vegetation downstream if the peak velocities and shear forces are great enough. With the increased flow rates and occurrence comes an increase in the erosion potential within the watershed. The impacts and impairment of this are discussed under sediment as a stressor.

The increased runoff from developed areas also has the potential to carry with it pollutants that would not otherwise enter the watercourse. For example in a residential development fertilizers may be carried by rainwater through the engineered stormwater conveyance system and be discharged to a river. Hence if the increased runoff were controlled not only would the stream experience less impact due to changes in hydrologic flow but would also not receive the fertilizer applied to the yard, in the above example.

A good discussion of the impacts of hydrologic flow may be found in "Hydrologic Impacts Due to Development: The Need for Adequate Runoff Detention and Stream Protection" by the MDEQ May 2002.

The loss of wetlands and connected floodplains in the watershed results in the same hydrologic changes as discussed above. In addition, the loss of storage areas help prevent the movement of sediment, filter pollutants, provide habitat and support a wide diversity of plants and animals.

Indicators

Many different indicators may be used for hydrologic flow. The most obvious indicator is that of the flow profile itself monitored throughout the day as it is at a USGS gauging station. The challenge with gauging station data is in interpretation based on all of the other variables affecting flow, for example precipitation, temperature, wind, length of records, etc. Flashiness indices are one method of analyzing flow records. The term flashiness reflects the frequency and rapidity of short term changes in stream flow, especially during runoff events. A variety of indices have been developed to describe natural flow regimes, their degree of alteration, and progress in their remediation.

Other indicators of changes in hydrologic flow look at the impact left behind such as streambank erosion, embeddedness, and population and biodiversity of organisms.

Erosion of streambanks is a natural process; severely eroding streambanks may be an indicator of changes in the hydrologic flow regime. Various methods are available to monitor the rate of eroding streambanks; these typically center around some type of reference marks or pins. Photographic monitoring also provides some reference framework for this. Fallen trees into the river may be an indicator of active erosion although this may be difficult to tell. The presence of exposed roots on the

riverbanks with the fine roots in tack (looks like the roots are hairy) may indicate eroding streambanks.

The loss of storage may be calculated based on mapping, survey data, and perhaps modeling and used as an indirect measurement of the hydrologic change.

Water Quality Standards

Water quality standards specific to hydrologic flow are not available. The water quality rules discussed under the MDEQ's administrative rules focus on chemical composition, taste or odor producing substances, radioactive substances, plant nutrients, microorganisms, dissolved oxygen, and temperature. The rules surrounding floodplain also do not address hydrologic flow specifically but rather look to net increases to the floodplain, typically the one percent probability floodplain (100-year). Since hydrologic flow variations are in and of themselves not regulated, attention must be focused on the impacts associated with the changes of hydrologic flow.

Available Data

As discussed in Chapter 3, stream flow data are available at USGS gauging stations. In the subwatershed, there are two locations where sufficient stream flow data exist to conduct a meaningful analysis. These sites (#04164000 on the Clinton River near Fraser at Garfield Road; and #0416550 on the Clinton River in Mt. Clemens at Moravian Drive) are detailed in Chapter 3.

Land use data and aerial mapping are available to estimate the percent of imperviousness, discussed in Chapter 3. Soil mapping information is available from the NRCS which is used in hydrologic flow computations. Flow conveyance information is available from the respective County Drain Commissioner's offices as well as from some municipalities.

Information on indicators is available in the form of organism biodiversity and population data (discussed in Chapter 3), and physical characteristics as observed from the various inventory and screening efforts previously discussed.

Load Estimates

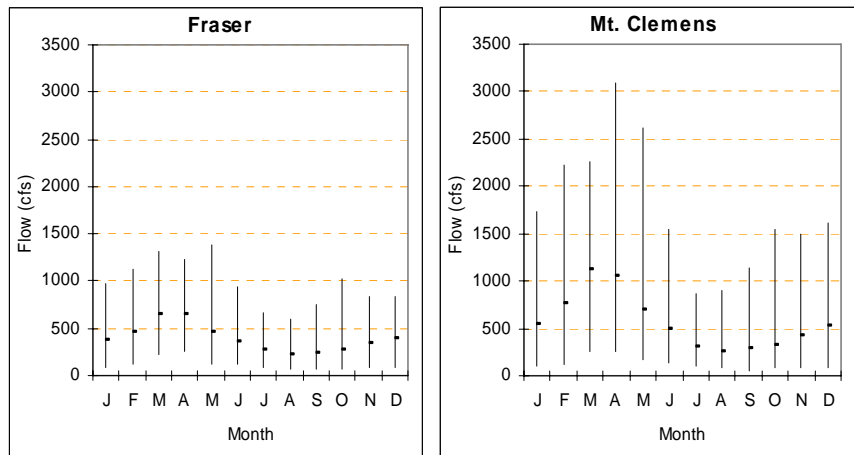
Load estimates for hydrologic flow are not specifically available rather surrogate estimates are used, namely the stream flow variations, flashiness indices and the amount of imperviousness within the watershed.

Figure 5-7 shows the monthly mean stream flows (in cfs) for the entire data span at the two USGS stations.

The vertical bar above each month illustrates the range of flow recorded and the horizontal tick mark on each vertical bar is the monthly mean stream flow. This is meant to illustrate the flow variability within each month and also between the months.

The flow data show the yearly variance in flow from January, increasing until its peak in March/April, decreasing to its lowest in August, then increasing again.

Figure 5-7. Monthly mean stream flows.



As one would expect, the downstream gage exhibits greater mean flows and greater variances in flows. For example, the stream flow at the Fraser gauge had a maximum annual mean of 563 cfs in 1985 with a monthly variation from 72 cfs in October 1953 to 1,352 cfs in May of 1956. The Mt. Clemens gauge had a maximum annual mean of 1,959 in 1975 with a monthly variation from a 51 cfs in July 1934 to a high of 3,090 cfs in April 1947.

The preceding analysis only addresses flow variability. One common metric used to characterize the change in basin response is a stream flashiness index. Flashiness is a characterization that quantifies the time response of a river to a rainfall event. In this analysis, the flashiness index used was based on a method described in a paper by researchers from Heidelberg University (Baker, et al, 2004) in the Journal of American Water Resources Association (see 'Flashiness Index' sidebar for additional information).

Figure 5-8 and 5-9 present the results for such an analysis at the two gages of interest in the subwatershed (USACE, 2005).

R-B Index to Track Changes in Flashiness

The Richards-Baker, or "RB" index is a ratio of the absolute value of the sum of the daily flow changes to the sum of the total daily flows. Although this index may vary spatially for a particular year, the temporal trend of this index is a relative indication of basin response to rainfall and is a good indicator of hydrologic changes in the watershed.

Figure 5-8. Flashiness indices and trend at the Fraser gage.

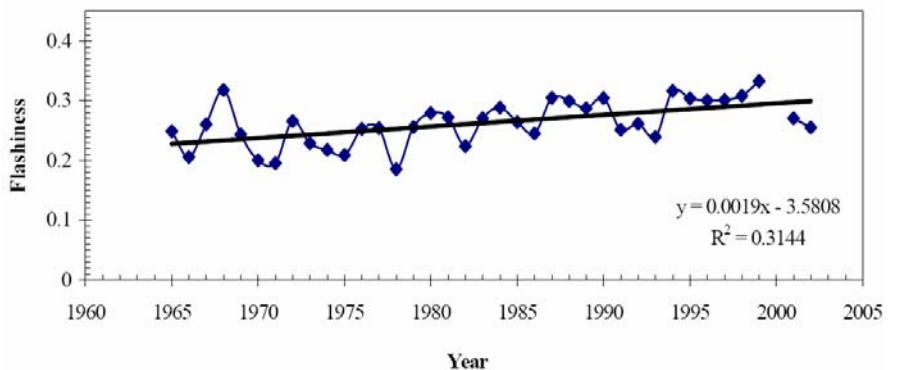
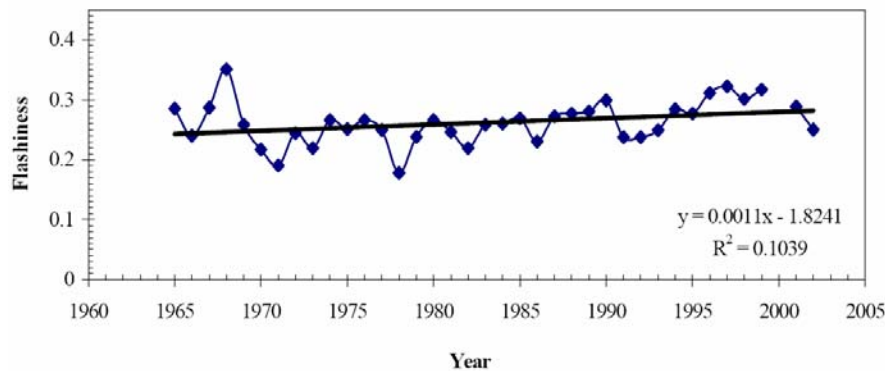


Figure 5-9. Flashiness indices and trend at the Mt. Clemens gage.



As can be seen in the figures, the flashiness index shows an increasing trend over the last 35 years. As any rainfall deviation over this period was statistically insignificant, this indicates that the Clinton River is generally becoming more responsive (exhibiting higher peak flow rates) most likely due to increasing impervious surfaces in the river's headwater areas.

A visual representation of the impervious cover from the land use data can be found in Chapter 2. The remaining discussion is based on this data as the impervious percentage coefficients were derived based on regional information.

The impervious cover for the subwatershed as a whole is 20.9 percent. The Gloede Drain, Central Main Branch and East Main Branch catchments have the greatest percentages of impervious surface, with over 26 percent each. The North Middle Branch catchment has the lowest impervious percentage at 8.4 percent. The other catchments have impervious percentages between 16.3 percent and 20.8 percent.

Analysis of stream systems across the country seems to indicate that there are thresholds at which watershed imperviousness results in measurable degradation of waters. The Impervious Cover Model (ICM) (Schueler, 1994) describes this relationship, some threshold values of imperviousness, the characteristics of streams impacted by imperviousness, and recommended actions to address issues in these streams.

The ICM, although a powerful tool to predict the quality of streams based on impervious cover change, has limitations and is not an absolute indicator. It is not generally applicable at scales greater than 10 miles and is based primarily on data from the northwest portion of the U.S. It is important to understand that the ICM is applicable at a single point along a waterbody; the analysis of imperviousness must consider the entire area of land tributary to that point. From the information presented above, it can be said that the Middle Branch of the Clinton River at the outlet of the West Middle Branch catchment has a tributary area that is 20.8 percent impervious and therefore falls within the impacted category. While the North Middle Branch catchment has an impervious area of only 8.4 percent, the ICM classification of the Middle Branch of the Clinton River at the outlet of the North Middle Branch catchment must include the total tributary area, which includes the West Middle Branch. This total area is then approximately 15 percent impervious and the river is classified as impacted at that location.

While outside the scope of this plan, it is recommended, in the future, to properly analyze the streams in the subwatershed in the context of the ICM. This involves defining drainage areas for numerous points along each stream to be analyzed and conducting the impervious analysis as described in the beginning of this section. At this point, it can be said, based on the catchment-aggregated data, that the impervious coverage for a given catchment can be compared to the ICM values to determine the likely classification of the small streams in that catchment. The remaining discussion in this section approaches the topic in such a manner.

As a whole, the subwatershed is affected by the high percentage of imperviousness. While some areas are expected to exhibit serious problems, others have impervious levels that imply the possibility to maintain high levels of water quality and general waterbody health.

While short-term actions for areas most affected by impervious surfaces are related to minimizing existing problems, the long-term outlook for these areas can be geared towards restoration if the right steps are taken. However, one of the purposes of the ICM is to identify streams that are outside of the severe impacts of imperviousness, so that limited resources can be funneled towards the protection of these resources. This approach is much more cost-effective than trying to restore streams severely degraded by high levels of imperviousness.

It should also be noted that the suggested relationship between impervious cover and the expected stream quality was developed for urban subwatersheds (typically with a drainage area less than 10 square miles) and may not accurately reflect conditions for agricultural areas.

Critical Areas

The critical areas for hydrologic flow are the highest developed areas as estimated by the impervious cover analysis. The more imperviousness associated with a given site, the higher the flashiness, the greater the peak flows will be increased, and the greater the total runoff volume due to the reduction in evaporation, transpiration, infiltration and storage.

All impervious areas which are directly connected to a stormwater conveyance system (often referred to as DCIA or directly connected impervious areas) should be considered for restoration potential. The areas with a higher percent impervious may be given higher priority based on their potential to more adversely affect the receiving water body. Likewise impervious areas which have a high potential for containing other pollutants should also be given a higher priority over impervious surfaces with no other pollutants.

When considered on the subwatersheds level those subwatersheds which have a percent imperviousness greater than or equal to 10 percent are considered the critical areas. Three categories are provided:

1 Urban Drainage Catchments

These areas are comprised of those with impervious cover greater than 60 percent. No catchments fall into this classification.

2 Non-Supporting Catchments

These areas are comprised of those with impervious cover between 26 and 60 percent. The Gloede Drain catchment falls into the category of 'Non-supporting' implying that many waterbodies in the catchment may be affected by impervious cover such that they show impacted water quality, low biodiversity, and have unstable channel banks. Portions of the Central Main Branch and East Main Branch catchments also include the Clinton River corridor. Portions of the East Main Branch catchment drain to Lake St. Clair directly or through canals. Both of the catchments are classified in the 'Non-supporting' category and thus waterbodies within them are expected to show effects similar to those described for the Gloede Drain catchment. The downstream portion of the West Main Branch catchment can be classified as 'Non-supporting'. This catchment is land that drains essentially directly to the Clinton River as part of its corridor. Thus pollutants draining from impervious areas have a direct loading into the river.

3 Impacted Catchments

These areas are comprised of those with impervious cover between 11 and 25 percent. The West Main Branch catchment falls within the 'Impacted' category. Despite heavy build-out on the downstream end, the amount of imperviousness is mitigated by a large conservation area on the upstream end. The East and West Middle Branch catchments fall within the 'Impacted' category. Waterbodies in these catchments are expected to show some signs of degradation. Watershed protection activities in these catchments should focus on protecting the critical elements of water quality and implementing protection strategies that focus on reducing pollutant loads from existing impervious areas. It is important to recognize that the aforementioned catchments are 'headwater areas' for the Middle Branch of the Clinton River and the fact that they are not dominated by impervious impacts is a positive in terms of future water quality potential. Refer to Chapter 2 for additional discussion concerning headwater areas.

Keep in mind that regardless of the overall subwatershed area weighted percent impervious, all directly connected impervious areas are good candidates for restoration potential.

For protection consideration, critical areas are considered those that have an impervious cover less than 10 percent in the category of "Sensitive." These are generally the undeveloped parcels or parcels with open green space included. The highest priority is given to the undisturbed tracks of land. Only one catchment, the North Middle Branch, falls in the 'Sensitive' category. One would expect that the waterbodies in this catchment will be the least impacted. Watershed protection activities in this catchment should focus on protecting the high quality elements of the waterbodies.

Load Reduction Targets

No specific load reduction is targeted for hydrologic flow. Rather the target is to see no effective upward trend for the R-B Index. Trending of the Index should be looked at on no less than a five year basis.

No specific target is set for the impervious cover analysis. The desire is to see no "effective" increase in hydraulically significant percent impervious. Hydraulically significant impervious areas are those impervious areas

directly connected to the receiving water. The intent is not to limit development and consequently the impervious area, but rather when development occurs to do so in an environmentally friendly manner such as the premise of low impact development techniques.

The target for the wetlands and floodplains is to see no net loss of additional storage within the watershed.

Monitoring Progress

Use of the R-B Index will be used at the two USGS gauging stations to monitor progress over time. Trending of the Index should be looked at on no less than a 5 year basis and not annually.

Progress will also be monitored through the other indicator parameters as identified in the *Indicator* section.

Improvement Ideas

To reduce the flashiness of a stream the high impervious cover areas may be retrofitted to slow down the runoff discharge and promote the use of infiltration and evapotranspiration. This may be accomplished through the use of bioretention and infiltration practices such as rain gardens, green roofs, porous pavement and vegetated swales. The use of detention facilities is appropriate to reduce the peak discharge however these types of facilities do not generally reduce the total volume of runoff discharged and therefore are not as effective as some other means.

For new development and significant redevelopment areas development standards should be put into place promoting the use of low impact development techniques. Public education and input should be included in formulating development standards.

Directly related to the flow regime stemming from high impervious areas is the ability and tendency of the runoff to pick up other pollutants and discharge them to the receiving waters. In order to minimize the impact of this any retrofit projects undertaken to reduce the discharge should also include best management practices to reduce the pollutants carried by the stormwater. In addition, good housekeeping practices and education should be included to reduce the opportunity for the pollutants to come in contact with the stormwater.

The degradation and loss of storage should also be thwarted by first completing inventories and assessments of the existing wetlands and floodplains and then providing protection measures. In addition, those areas capable of being restored should be prioritized and worked on as possible.

Critical Area Summary

Based on the critical area analyses presented in the previous sections, BMPs applied in urban areas have the potential to mitigate numerous stressors. Additionally, BMPs applied in agricultural area may do the same.

Other Stressors

Aside from the stressors discussed above in detail, other known stressors are present in the watershed. For each of these stressors, the sources and causes are identified.

Contaminated Sediments

Chemicals such as PCBs, metals (e.g., mercury, lead, zinc), and pesticides tend to bind to particles and collect in bottom sediments. Elevated concentrations of these chemicals have been documented over several decades in a number of locations along the Clinton River from Pontiac to

the mouths of both the river and the spillway (EPA, 2003). According to studies conducted during the last decade, the subwatershed contains some of the most contaminated areas within the Clinton River AOC (ECT, 2005). Table 5-17 presents the potential sources and causes of contaminated sediments in the subwatershed. The sources of these contaminants include historical point source discharges, as well as existing nonpoint sources. Contaminated sites, such as landfills and leaking underground storage tanks, might also contribute pollutants contaminating sediments. More work is necessary to understand the sources and causes of contaminated sediments, including the mixing and transport of sediments. When present at elevated levels in sediments, chemicals can kill or harm bottom-dwelling organisms and can also accumulate in aquatic organisms and move up the food chain to fish, shellfish and eventually humans. Contaminated sediments have also resulted in a restriction to dredging activities because of the concern for re-suspending chemicals currently buried.

Table 5-17. Contaminated Sediments - Sources and Causes

Sources	Cause
Resuspension of buried contaminated sediments	Disturbance from storm events Disturbance from recreational and navigational activities
Contaminated sites (landfills and underground storage tanks)	Age of materials Lack of maintenance and monitoring
Stormwater runoff	Automotive fluids and by-products on impervious surfaces Improper disposal of hazardous materials Improper materials storage and good housekeeping practices

Polychlorinated Biphenyls

Polychlorinated Biphenyls (PCBs) were commonly used in industrial and commercial equipment including heat transfer systems and televisions as well as in paints, plastic and rubber products, pigments, dyes and carbonless copy paper until PCBs were banned in 1976. Table 5-18 lists potential sources and causes of elevated PCB levels in the subwatershed. The Clinton River Spillway is noted for having elevated levels of PCBs. According to the EPA, PCBs are known to cause cancer in animals, cause problems in human immune, reproductive, nervous and endocrine systems and affect intellectual development of children and adults (EPA, 2006).

Table 5-18. PCBs - Sources and Causes


Sources	Cause
Stream Bottom Sediment	Plant Discharges Lack of Convenient Disposal Facilities Permitted Usage
Brownfield Runoff and Subsurface Leaching	Plant Discharges Lack of Convenient Disposal Facilities Permitted Usage

Habitat Alteration

Habitat alteration is affecting the fisheries, other aquatic life, and wildlife. Habitat loss has resulted from the urbanization of the watershed and the conversion of the natural land cover to parking lots, buildings, homes, and lawns. In addition to the direct loss of stream habitat, the increased imperviousness has also resulted in a significant modification to the natural flow regime. High quality stream habitats with intact riparian zones and natural channel morphology are essential to a healthy aquatic community because they provide shelter, spawning areas, and can help filter excess pollutants such as nutrients and sediment.

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